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RESULTS FROM TIEN-SHAN SURVEY TO SEARCH FOR VARIABLE STARS: OBSERVATIONS, TARGET SELECTION AND DATA PROCESS

Abstract. We present the first results of the photometric survey at Tien-Shan Observatory (TSO) of the fields around Galactic equator using Zeiss-1000 telescope. Here we report on criteria selection of target fields, observation strategy and statistics of photometric observations. We also provide description of data process and differential photometric reduction to extract differential light curves. In total, 23 fields in the range of 40°-210° Galactic longitude and ±5° Galactic latitudes were observed during 2014-2018. Each filed was observed for at least 3 hours long with cadence range 30-180 sec in Johnson-Cousine filters V and R, or in integrated light. As a result, long duration light curves for about 10 000 stars were obtained. A visual inspection of the light curve from each run was carried out for each star in the 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 signs of variability. Analysis of the light curves of these stars leads to the identification of 33 variable stars. Among them, 31 stars are previously unknown variables not presented in catalogs of variable stars.

Key words: CCD observations: data analysis; methods: light curve analysis, photometry.

Introduction. The TSO survey was initiated in 2018 as campaign in frame of program BR05236322 aims to search for compact and ultra-compact binary systems (UCB), including interacting binary systems (AM Cvn), uncatalogued variable stars of know type, unclassified variables and object with other type of variability phenomena. The survey initially was motivated by the fact that the observed number of AM CVn is 12 times less than was predicted [1]. Thus, the refinement of the amount of AM CVn can provide an opportunity to clarify the models of the formation of such systems and their evolution. Also, it was realized that survey observations can detect variable stars of other types of variability including those usable for asteroseismic studies, systems with exoplanets, etc.

Conducting survey observations to search for UCB and AM CVn by one observatory is justified by the fact that the periods of brightness variation in these objects are about several tens of minutes (the most interesting are systems with periods of 20-35 minutes or less), and the amplitudes from 1.0 to 0.01 in magnitudes [2], that is, are within the accuracy of photometry obtained on meter-class telescopes on TSO.

Selection of star fields for TSO survey. The main criteria for selecting star fields of interest for the survey is optimal star density on CCD frame. On one hand, it should not be too high for successful PSF photometry, and on the other hand, it should be sufficient for the high efficiency of the survey. Another criterion is availability of the selected field for long-time observations. For the current survey this criterion is ~3 hours, which is dictated by two the most important factors: 1) ability to observe up to 2-3 fields per night, 2) to detect periods of brightness variation from 1.5 hours and less, which is one of the main objectives of the survey. At last but not least, the selected fields should not overlap with targets from other survey campaigns, such as, for instance, VPHAS+ and OWS. All the above criteria are met by the fields located at ±5 degrees of galactic latitude and from 40 to 210 degrees of galactic longitude. Also, it is desirable to have relatively bright White Dwarf (WD) candidates as well as the absence of bright stars in the selected field to avoid contamination in case of long exposure. The presence of at least one WD candidate with a magnitude of 17.5 mag or brighter in the field was determined from the catalog analysis [3]. This choice is due to the combination of a requirement for the accuracy of photometry, exposure time and duration of observations.

The criterion of WD presence is due to the high scientific interest in the study of these objects. Most of the WD (25% to 50%) shows the presence of metals in their atmospheres, which is most likely the result of destruction of the remains of earth-type planets or asteroids in their vicinity. The study of planetary systems around WD makes it possible to conclude the formation of such systems in Main Sequence stars (MS), for which direct observations of planets are difficult. Thanks to "Kepler" space mission, many exoplanets have been discovered, but mostly near relatively cold and dwarf stars. The question arises-is this fact a reflection of reality, that is, some feature of the formation and evolution of planetary systems, or it is the result of "bad" statistics due to limitation of observations. Indeed, the most reliable parameters of exoplanets are determined by radial velocities, and this is difficult for large mass stars because for such stars the influence of exoplanet is quite weak. The same is true for very hot stars, which do not have sufficient absorption lines by which radial velocities can be confidently measured.

The study of planetary systems around WD allows us to extend the time scale of studies of the evolution of planetary systems to several billion years and, therefore, to impose additional restrictions on the theory of their formation and evolution. Statistics of observations of such systems will shed light on the problem of survival of planets at evolution period when the parent star passes the stage of the "red giant" and multiple events of expelling outer layers. The conclusions of the modern theories describing the process of survival of the planets are quite controversial. Besides, there are suggestions that the expelled envelope of a "red giant" can be a source of formation of new planets.

Moreover, observations of oscillating WD are of great interest for fundamental science, because the period changes in DAV-type WD can be caused by their cooling rates which provide an upper limit on the masses of axions that are considered as one of the candidates in components of "dark matter". Variation of oscillation periods of the DV-type WD allows us to test the nature of the interaction of leptons in the framework of some unified theories of electroweak interaction in the low energy regime.

Analysis of GAIA and OWS catalogs. As a result of the analysis of GAIA and SVO catalogs [3] the list of high-priority star fields satisfied the above-mentioned criteria is compiled and present in table 1. The fields location on the celestial sphere relative to the plane of the Galaxy is shown in figure 1, where the dotted line is depict Galactic equator, empty squares are the fields planned for observation, orange shows the fields with a single epoch of observations, blue squares are the fields observed in two epochs and green squares are the fields with several epochs of observations.

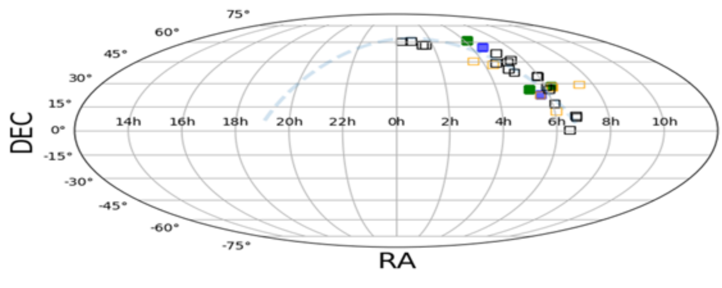

Figure 1 - The star fields locations, selected for TSO survey relative to galactic plane

Table 1 - The list of the high-priority fields selected for TSO survey

Field No.	RA [h:m:s]	DEC [d:m:s]	Field No.	RA [h:m:s]	DEC [d:m:s]	Field No.	RA [h:m:s]	DEC [d:m:s]
1	2	3	4	5	6	7	8	9
19-2	19:59:33	+24:54:46	19-5	20:00:39	+20:32:39	21-9	05:56:39	+35:09:33
18-6	04:22:18	+42:53:42	19-3	20:50:37	+36:14:14	21-6	06:02:28	+27:56:24
19-1	19:38:23	+26:39:56	19-4	01:26:48	+57:42:23	21-8	06:45:55	+08:36:52

Continuation of the table 1

1	2	3	4	5	6	7	8	9
19-6	19:57:57	+33:55:05	19-7	19:39:02	+26:55:38	21-7	06:44:16	+09:24:55
19-9	01:35:36	+57:31:29	19-8	00:17:14	+60:13:43	18-8	06:03:50	+12:22:19
20-1	22:16:59	+59:51:09	20-2	19:23:22	+20:21:00	18-7	04:33:40	+55:26:33
20-4	04:54:49	+39:52:35	20-3	04:34:49	+44:11:20	18-4	05:38:06	+22:32:49
20-7	19:44:12	+13:50:32	20-5	05:04:18	+37:31:18	18-9	06:14:59	+28:05:49
20-8	05:08:09	+44:50:38	20-6	20:37:16	+32:42:00	18-10	06:15:38	+27:50:00
21-1	05:20:41	+46:03:34	20-9	04:58:14	+51:06:56	16-1	05:16:36	+26:07:25
21-3	00:50:58	+60:31:17	21-2	21:47:42	+50:26:20	16-2	07:25:41	+29:27:18
21-5	06:28:32	+00:38:54	21-4	06:04:06	+17:07:31	16-3	04:07:06	+60:55:28
18-1	22:29:20	+52:10:38	18-2	05:38:35	+22:39:10	18-11	06:15:19	+28:13:03
18-3	23:01:15	+54:37:04	18-5	03:33:07	+45:25:44			

Observations and archive data. Observations were carried out at the TSO (76°58'18''.5E, 43°03'26''.3N, altitude is 2723 meters, international Observatory code is N42) on the meter class telescope Zeiss-1000 "Vostochny", equipped with Apogee Alta U16M CCD having Kodak KAF-16803 chip with physical pixel size of 9 μm and dimension of 4096×4096 pixels. A field corrector/focus reducer which reduces equivalent focal length to 6665 mm, is installed, which gives the telescope FOV of 19'×19' and a spatial resolution of 0''.56/pixel. For observations in 2016, the Zeiss-1000 "Vostochny" telescope equipped with Apogee Alta U9000 CCD camera having a Kodak KAF-09000 chip with the dimension of 3056×3056 pixels and physical pixel size of 12 μm was used. The telescope's FOV was the same as for observations in 2018-2019, but with scale of 0''.37/pixel. To improve the signal-to-noise ratio, observations were made in the second binning. In total, 12 fields were observed in 2019. Information on observations is given in Table 2, it can be seen that some fields were observed for several epochs.

Table 2 - Statistics of observations conducted in 2019

Field No.	Date [d/m/y]	Duration [h.]	V [frames]	Rc [frames]	Exposure [sec]	Field No.	Date [d/m/y]	Duration [h.]	V [frames]	Rc [frames]	Exposure [sec]
18-2	22/02/2019	3.5	161	---	60	18-9	27/02/2019	3.0	141	---	60
18-4	29/01/2019	3.8	155	---	60	18-9	12/03/2019	3.1	106	---	90
18-5	27/01/2019	3.3	---	100	60/120	18-9	08/02/2019	3.6	120	---	60
18-6	01/02/2019	3.5	153	---	60	18-10	13/03/2019	3.0	102	---	90
18-7	02/02/2019	4.1	178	---	60	18-11	20/03/2019	3.5	116	---	90
18-7	23/02/2019	4.7	220	---	60	18-8	05/03/2019	2.9	224	---	60

To search for variable stars using the technique of pipeline analysis [4], we also analyzed archival data of observations with the desired duration carried out in the period of 2016-2018. The statistics of these observations are given in table 3.

Table 3 - Statistics of archival data used for purpose of the survey

Field No.	Date [d/m/y]	Duration [h.]	No filter [frames]	V [frames]	Rc [frames]	Exposure [sec]	Field No.	Date [d/m/y]	Duration [h.]	V [frames]	Exposure [sec]
1	2	3	4	5	6	7	8	9	10	11	12
16-1	15/01/2016	7.2	732	---	---	20	16-3	01/11/2016	8.2	280	90
16-1	24/01/2016	7.7	762	---	---	20	16-3	04/11/2016	5.6	191	90

Continuation of the table 3

1	2	3	4	5	6	7	8	9	10	11	12
16-1	25/01/2016	8.6	857	---	---	20	16-3	07/11/2016	5.1	174	90
16-2	20/01/2016	6.9	---	---	800	20	16-3	09/11/2016	6.6	219	90
16-3	26/10/2016	8.1	---	254	---	90	18-1	05/12/2018	2.9	221	30
16-3	27/10/2016	8.5	---	277	---	90	18-2	05/12/2018	2.8	131	60
							18-3	15/12/2018	1.1	55	60

Data analysis. As the main tool for preliminary analysis of the data we use IRAF (http://ast.noao.edu/data/software) package. Averaged CCD frame of bias (Master Bias) is obtained by "*zerocombine*" task (*iraf.iraf.ccdred*) and dark current (Master Dark) is obtained by "*darkcombine*" task (*iraf.imred.ccdred*). Master Bias and Master Dark are additive sources of noise and must be subtracted from CCD image of the target (with Master Bias first subtracted from Master Dark). The heterogeneity of the sensitivity of the CCD (flat-field frame) is a multiplicative component, so the CCD image of the target should be divided by the flat-field. An averaged CCD flat-field frame (Master Flat) was obtained for each filter in which the object was observed and corrected for the dark current of corresponding exposure. To obtain Master Flat we use the "*flatcombine*" task (*iraf.imrad.ccdred*). The object frames were processed with "*ccdproc*" (*iraf.iraf.ccdred*) task using appropriate Master Dark and Master Flat frames.

To carry out PSF photometry of sources on pre-processed CCD frames, a software package implemented on *Python* utilizing such libraries as "*pyraf*", "*astropy*" [5], "*scamp*" [6], "*astroquery*" is used. More details can be found in [4]. Photometric parameters were determined as follows. Assuming that the PSF profile of the star is close to the Gauss function we have $\sigma_{PSF} = FWHM_{PSF}/2\times(2\ln 2)^{-1/2}$. Preliminary estimation of FWHM of the PSF was determined from observation conditions, i.e. from seeing parameter, which for TSO is ~2".5. The radius of the aperture to determine the total flux is set by the criterion of "five sigmas" $A_{ph} = 5\times\sigma_{PSF}$. The sky background level was determined within aperture $A_{sky} = 6\times\sigma_{PSF}$, in 5 pixels wide ring. The size of the PSF profile used for approximation is $R^{fit}_{PSF} = 5\times\sigma_{PSF} - 1$. The saturation level was assumed to be 60000 ADU.

The "*scamp*" package [6] is used for the astrometric plate solution and "*SExtractor*" [7] is used to search for objects on the CCD frame. An example of the accuracy of the obtained photometric estimates is shown in figure 2. Analysis of photometric results was carried out only for those stars whose photometric errors did not exceed 0.05 mag. This choice is due to the aim of finding variable stars with an amplitude of brightness variation of the order of hundredths of a magnitude.

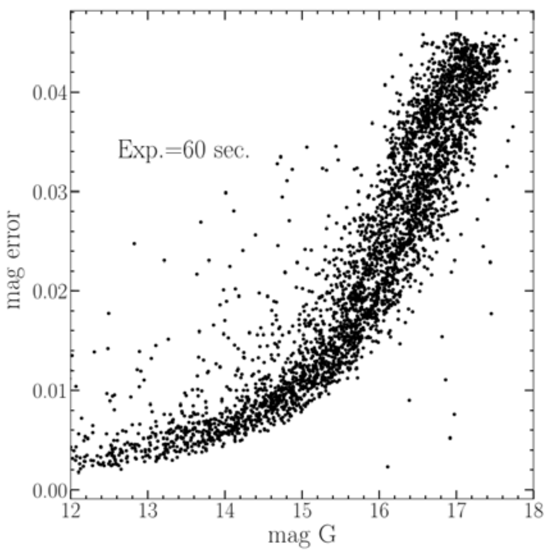

Figure 2 - Dependence of photometric precision (mag error) on stellar magnitude (mag G)

To obtain the light curves of the differential magnitudes of each of the stars in the CCD frame, we use the method of constructing a synthesized reference light curve utilizing all the stars in the field. This choice is mainly dictated by the following factors: 1) the construction of a synthesized reference curve for all stars in the field can significantly reduce the impact of inaccurate photometry for each star, 2) one may not knows the spectral class of the target star, and therefore cannot adequately choose the comparison star for each target with suspected variability. Since the total number of stars in a CCD image ranges from several hundred to several thousand, we can assume that the photometric accuracy of the reference light curve is much higher than that of the analyzed star and does not take into account errors of referent light curve in further analysis.

A total of 23 fields were analyzed using the pipeline procedure. Photometric measurements were obtained for ~10 000 stars with duration of observations of at least 3 hours for each run. A visual inspection of the light curve from each run was carried out for each star in the 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 signs of variability. The full list of suspected variable stars is presented in table 4.

Table 4 - The list of suspected variable stars

Field No.	GAIA ID	RAJ2000 [h:m:s]	DECJ2000 [d:m:s]	Field No.	GAIA ID	RAJ2000 [h:m:s]	DECJ2000 [d:m:s]
16-1	3420722996343786496	05:16:09.7	+26:02:45.3	18-1	2000667342122793472	22:30:15.9	+52:00:02.7
	3420728150304526976 (KUV 05134+2605, ZZB)	05:16:27.8	+26:08:37.2		2000668544713613952	22:30:12.2	+52:03:22.5
	3420726084425443200	05:15:59.1	+26:03:25.9		2000677993641422208	22:29:14.5	+52:03:02.4
16-3	473900064311871488	04:06:19.7	+60:56:30.6		2000680742420926976	22:30:27.8	+52:06:18.4
	473906008546567168	04:06:18.6	+61:03:08.5		2000681876292067968	22:30:10.9	+52:08:57.1
	473706893862387328	04:07:13.0	+60:47:18.3		2000684586402884864	22:29:54.1	+52:08:48.6
	473712872456844544 (NGC 1501, RPHS)	04:06:59.4	+60:55:14.4		2000685758942457728	22:29:44.1	+52:12:16.6
	473900304830038144	04:06:13.4	+60:57:13.4		2000686239978998400	22:30:08.0	+52:14:34.3
18-2	3404213726175547776	05:38:27.3	+22:38:11.4		2001434835597456768	22:28:45.8	+52:17:00.5
	3404200257158109824	05:38:54.1	+22:32:08.4	18-7	277089853758788352	04:34:22.1	+55:31:36.5
	3404217746264940032	05:38:10.8	+22:41:01.7		277091262508123264	04:33:06.3	+55:28:02.3
18-4	3404189944938309120	05:37:26.4	+22:30:51.7		277091739248814208	04:33:13.7	+55:31:56.6
18-5	241766668329744896	03:33:41.1	+45:23:50.6		277092155861283712 (TYC 3736-373-1)	04:33:24.6	+55:33:07.3
	241771856649828992	03:32:58.5	+45:21:07.0		277093014852191616	04:34:25.9	+55:34:13.0
18-6	229267969902029696	04:23:13.9	+42:49:37.7		277091911047501568	04:33:36.4	+55:31:42.7
18-10	3433368376498172160	06:15:21.9	+27:50:33.0	18-8	3342732093967192576	06:03:46.4	+12:28:08.8
18-11	3433415586778288768	06:15:55.7	+28:12:34.7				

Conclusion. Survey observations of 15 selected fields were carried out on TSO using Zeiss-1000 telescope in 2019. Photometric pipeline data analysis conducted for 23 fields, including observations for 2016 and 2018. As a result, light curves for about 10 000 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. To determine the type of detected variable stars, it is necessary to investigate the amplitude-period parameters of these candidates, their location on color-magnitude diagram and to carry out spectral analysis. These results will be presented in the separate paper.

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АЙНЫМАЛЫ ЖҰЛДЫЗДАРДЫ ІЗДЕУ БОЙЫНША ТЯНЬ-ШАНЬДЫҚ ФОТОМЕТРИЯЛЫҚ ШОЛУДЫҢ НӘТИЖЕЛЕРІ: БАҚЫЛАУЛАР, НЫСАНДАРДЫ ТАҢДАУ ЖӘНЕ МӘЛІМЕТТЕРДІ ТАЛДАУ

Аннотация. 2018 жылы Тянь-Шань обсерваториясында BR05236322 бағдарламасын іске асыру аясында, ықшам және ультра ықшам екілік жүйелерге (UCB) үміткерлерді іздеуді, соның ішінде өзара әрекеттесетін екілік жүйелерді (AM Cvn) іздеуге арналған байқау науқаны, бұрын белгісіз ауыспалы жұлдыздар, өзгермелілігі белгісіз типті жұлдыздар. Бұл шолу AM CVn мөлшері болжанғаннан 12 есе аз болғандығымен негізделген [1]. Осылайша, AM CVn нөмірін қайта қарау мұндай жүйелер мен олардың эволюциясының модельдерін жарықтандыруға көмектеседі. Сонымен қатар, зерттеу жұмыстарын бақылау барысында басқа ауыспалы жұлдыздарды, оның ішінде астросеизмге қызығушылық танытатын объектілерді, экзопланеталары бар жүйелерді және т.б. зерттеуге болатындығы анықталды.

Zeiss-1000 телескоптары көмегімен Тянь-Шань обсерваториясында (TSAO) Галактика жазықтығында таңдалған аймақтарды зерттеудің алғашқы нәтижелері келтірілген. Мақалада күтілетін өрістерді таңдау әдістемесі, бақылаулар мен мұрағатталған деректер статистикасы, дифференциалды жарқырау қисықтарын алу мақсатында қолданылған деректерді талдау мен дифференциалды фотометрия процестері сипатталған. 2014-2019 ж аралығындағы бақылау маусымдары кезінде 40° -дан 210° -қа дейінгі галактикалық бойлық пен ± 5° галактикалық ендік бойынша 23 облыс анықталды.

Байқау Zeiss-1000 «Восточный» метрлік класты телескопында, Apogee Alta U16M CCD CCD камерасымен жабдықталған, Kodak KAF-16803 чипті процессоры бар, пиксель өлшемі 9 мкм және жалпы чиптің өлшемі 4096 × 4096 пиксель. Өрісті түзеткіш (фокусты төмендеткіш) эквивалентті фокусты 6665 мм-ге дейін төмендетуге мүмкіндік берді, ол өрістің өлшемін 19'×19' және кеңістіктік 0'' 56 пиксел/пиксель берді. 2016 жылы бақылаулар Zeiss-1000 «Восточный» телескопында да жүргізілді, бірақ Apogee Alta U9000 CCD CCD камерасымен Kodak KAF-09000 чипі бар, өлшемі 3056 × 3056 пиксель және физикалық өлшемі 12 мкм. Сонымен бірге, телескоптың өрісі 2018-2019 жылдардағы бақылаулармен бірдей болды, бірақ масштабы 0''. 37/пиксель. Сигналдар/шу деңгейінің жоғарылауына қол жеткізу үшін үшінші биннингте бақылау жүргізілді.

Таңдалған облыстардың әрқайсысы Johnson-Cousin V және R кең жолақты сүзгілерінде, сондай-ақ толық жарықта 30 секундтан 180 секундқа дейін, кем дегенде 3 сағат үздіксіз бақыланды.

Фотометриялық талдау үшін біз Python ортасында және “*pyraf*”, “*astropy*” [5], “*scamp*” [6], “*astroquery*” кітапханаларында жасалған бағдарламалық жасақтаманы қолдана отырып, PSF фотометрия әдісін қолдандық. Тікелей дифференциалды жарық қисығын алу үшін өрістегі барлық жұлдыздардың фотометриялық ақпаратын қолдана отырып, синтезделген анықтамалық жарық қисығын құру әдісін қолдандық. Бұл стратегияны таңдау келесі факторларға байланысты болды: 1) синтезделген салыстыру жарық қисығы бір салыстыру жұлдызының шу деңгейін айтарлықтай төмендетеді 2) біз зерттелген жұлдыздың спектрлік класын жиі білмейтіндіктен, сәйкес келетін жұлдызды дұрыс таңдай алмаймыз. CCD кадры шеңберіндегі жұлдыздардың жалпы саны жүздеген немесе тіпті мыңға жетуі мүмкін болғандықтан, фотометрияның дәлдігі зерттеліп жатқан жұлдыздың жарық қисығындағы шу деңгейі ғана болады деп болжауға болады.

Нәтижесінде, бақылаудың әр жиынтығы үшін шамамен 10 000 жұлдыз үшін ұзақ мерзімді жарық қисықтары алынды және әр учаске үшін бақылаудың жалпы ұзақтығының 75% -дан кем емес фотометриядан өткен әр жеке өріс жұлдыздарының жарық қисықтарынан визуалды тексеру жүргізілді, бұл жұлдыздарды біркелкі анықтауға өзгергіштік белгілері мүмкіндік берді. Осы жарық қисықтарының талдауы бойынша өзгеретін 33 жұлдыз анықталды. Олардың ішінде 31 жұлдыз өзгермелі жұлдыздар каталогында көрінбейтін жаңа болып табылады.

Түйін сөздер: CCD бақылаулары: деректерді талдау; әдістер: жарқырау қисығын талдау, фотометрия.

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РЕЗУЛЬТАТЫ ТЯНЬ-ШАНСКОГО ФОТОМЕТРИЧЕСКОГО ОБЗОРА ПО ПОИСКУ ПЕРЕМЕННЫХ ЗВЕЗД: НАБЛЮДЕНИЯ, ВЫБОР ОБЪЕКТОВ И АНАЛИЗ ДАННЫХ

Аннотация. В 2018 году, в рамках выполнения программы BR05236322 на Тянь-Шанской обсерватории, была инициирована кампания по проведению поисковых наблюдений для поиска кандидатов в компактные и ультра-компактные двойные системы (UCB), включая взаимодействующие двойные системы (AM Cvn), ранее неизвестные переменные звезды, звезды с неизвестным типом переменности. Данный обзор был мотивирован тем фактом, что количество AM CVn в 12 раз оказалось меньше, чем предсказано [1]. Таким образом, пересмотр числа AM CVn помог бы пролить свет на модели формирования таких систем и их эволюцию. Кроме того, было выяснено, что в процессе обзорных наблюдений представляется возможность исследовать другие переменные звезды, включая объекты интересные для астросейсмологии, системы с экзопланетами и др.

В данной статье представлены первые результаты обзора избранных площадок в плоскости Галактики, выполненные на обсерватории Тянь-Шань (ТШАО) с использованием телескопов Цейсс-1000, описана методика выбора перспективных полей для обзора, статистика полученных наблюдений и архивных данных, процесс анализа данных и дифференциальной фотометрии с целью получения дифференциальных кривых блеска. В общей сложности были проведены наблюдения 23 площадок в диапазоне от 40° до 210° галактической долготы и ±5° галактической широты в течении наблюдательных сезонов 2014-2019 годов.

Наблюдения были выполнены на телескопе метрового класса Цейсс-1000 “Восточный”, оснащенный ПЗС-камерой Apogee Alta U16M CCD с чипос Kodak KAF-16803, с размером каждого пикселя 9 мкм, а полный размер чипа 4096×4096 пикселей. Корректор поля (он же редьюсер фокуса) позволил сократить эквивалентный фокус до 6665 мм, что дало поле размером 19'×19' и пространственным разрешением 0".56/пиксель. Наблюдения в 2016 были выполнены также на телескопе Цейсс-1000 “Восточный”, но уже с ПЗС камерой Apogee Alta U9000 CCD с чипом Kodak KAF-09000 размером 3056×3056 пикселей и физическим размером каждого пикселя 12 мкм. При этом поле телескопа было таким же, как и для наблюдений в 2018-2019, но с масштабом 0".37/пиксель. Для достижения более высокого отношения Сигнал/Шум наблюдения выполнялись в третьем биннинге.

Каждая из выбранных площадок наблюдалась непрерывно на протяжении, как минимум, 3 часов с экспозицией от 30 сек до 180 сек с использованием широкополосных фильтров V и R системы Джонсона-Кузина, а также в интегрированном свете.

Для фотометрического анализа использовалась методика PSF-фотометрии с использованием разработанного в среде *Python* программного обеспечения и библиотек “*pyraf*”, “*astropy*” [5], “*scamp*” [6], “*astroquery*”. Для получения непосредственно дифференциальных кривых блеска был использован метод построения синтезированной референтной кривой блеска с использованием фотометрической информации всех звезд в поле. Такой выбор стратегии был продиктован следующими факторами: 1) синтезированная кривая блеска сравнения значительно уменьшает вклад шума от отдельно взятой звезды сравнения; 2) поскольку мы зачастую не знаем спектральный класс исследуемой звезды, мы не можем правильно выбрать соответствующую звезду сравнения. Поскольку общее число звезд в поле ПЗС-кадра может достигать сотен и даже тысяч, мы можем сделать предполагаем, что точность фотометрии только уровнем шума в кривой блеска исследуемой звезды.

В результате были получены продолжительные кривые блеска для порядка 10000 звезд. для каждого сета наблюдений и для каждой площадки была выполнена визуальная проверка кривых блеска каждой отдельной звезды поля, прошедшей процедуру фотометрии, как минимум, на протяжении 75% от общей продолжительности наблюдений, что позволило выявить звезды с однозначными признаками переменности. В результате анализа этих кривых блеска было выявлено 33 переменные звезды. Среди них 31 звезда – это новые, не представленные в каталогах переменных звезд.

Ключевые слова: ПЗС наблюдения: анализ данных; методы: анализ кривых блеска, фотометрия.

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