CCD VRI photometry of the old open cluster NGC 7142

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Photometry of 2194 stars in the field of the open cluster NGC 7142 in VRI filters was performed to search variable stars. Eleven probable variable stars were found using robust median statistics. We separated probable cluster members using proper motions from UCAC3 and our photometric diagrams. Also we used our VRI photometry and JHK photometry from 2MASS to improve the age and the reddening for the cluster assuming the distance 1683 pc from WEBDA database.

Key words: open clusters and associations: general, stars: variables: general, techniques: photometric

INTRODUCTION

The old open cluster NGC 7142 (ra = $21^h 45^m 09^s$. $dec = +65^{\circ}46'30'' (2000), 1 = 105^{\circ}.347, b =$ 9^{circ} .485) is located in Cepheus, a star-rich region of the Milky Way. Few arcminutes aside one can find young open cluster NGC 7129 surrounded by a reflecting nebula as a background, which partially obscures some regions in NGC 7142, therefore absorption in the field is irregular. Trumpler [12] defined the cluster as II 1m. Subsequent work on the cluster was reported by Hoag [5] (first color-magnitude diagram (CMD) of the cluster), by Sharov [10] (interstellar absorption, star counts) and by van den Bergh[14], who paid attention to the similarities of the CMD of NGC 7142 to those of the old open clusters NGC 188 and M67. Later van den Bergh & Heeringa [15] estimated the distance modulus as $(m-M)_0 = 12.5$ and the age as lying between M 67 and NGC 188 ages. Crinklaw & Talbert [2] performed the first CCD photometry and derived new distance of $(m-M)_0 = 11.4 \pm 0.9$ for the cluster, also they found one variable star (V375 Cep) and proposed that stars of WUMa type could be found in the cluster. Rose & Hintz [8] performed a search for low amplitude short-period variables up to 15^m in a core region of NGC 7142. This paper presents the new CCD VRI photometry of the cluster.

OBSERVATIONS AND DATA REDUCTION

All observations were performed between February 2 and March 21, 2010 at Kourovskaya Astronomical Observatory with Hamilton system telescope

Astrometrical cross matching and aperture photometry of more than 500 frames were processed with IRAF software package [11]. For the following reduction and differential photometry of 2194 stars in the field of NGC 7142 covering $30'\times 30'$ a special console program in C++ language was written. The program executes algorithms described by Everett & Howell [3]. Our photometrical errors for stars of 11^m-15^m are less than 0.05^m in all bands. We transformed our instrumental magnitudes to the Johnson-Cousins VRI system using CCD photometry of our field from [2, 4, 7]. Our instrumental magnitudes system has a negligible dependence on magnitude (slope= -0.00013 ± 0.00012). The rms deviation from standard system is $\pm0.035^m$.

Table 1: Observations

band	nuber of frames	exposure time, s
V	483	120
${ m R}$	115	60
I	664	180

CCD VRI PHOTOMETRY

JHK photometry from 2MASS Point Source Catalogue was used to estimate reddening and eliminate cluster members using CMD and Q-index diagram. For the last one the sequence of non-reddened stars

MASTER II of MASTER Robotic Net [6]. The telescope has two identical tubes with focal length = 1000 mm, aperture = 400 mm, field of view $2^{\circ} \times 2^{\circ}$, CCD ALTA U16M cameras, 4096×4096 px, and scale: 1.8''/px. Number of frames and exposure time are presented in Table 1.

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was calculated from the Table 1 of [13]. We also used stars' proper motions from UCAC3 to exclude foreground stars. The most part of stars in the core region has $\mu_{\alpha} = (-2.5 \pm 6) \, \text{mas/yr}$, $\mu_{\delta} = (1 \pm 6) \, \text{mas/yr}$. Stars of core region (diameter=10') inside 3σ interval of the proper motions having the identical reddening were determined as probable cluster members. Probable cluster members are shown in Fig. 1 where the found variable stars are denoted with numbers. The best fit yielded reddening of $E(J-H) = 0.13 \pm 0.05$, the error was estimated as a half-width of the cluster sequence.

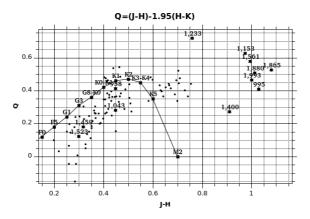


Fig. 1: Q vs. J-H for cluster stars (points), variable stars (asterisks); Q-index curve is shown with line with rectangles.

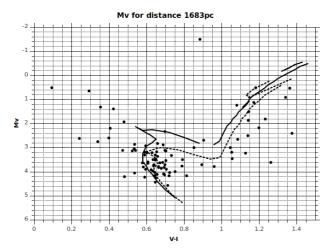


Fig. 2: M_V vs. V-I: points denote cluster stars, solid and dashed lines correspond to log age 9.4 and 9.6 respectively.

The CMD of the probable cluster members is shown in Fig. 2 with isochrones from [1] of logarithm ages of 9.4 and 9.6 shifted with our estimation of interstellar absorption and true distance modulus $12^m.23$ calculated using the cluster distance 1683 pc from WEBDA database. The best fit of isochrones gives estimation of logarithm age 9.55.

We made no attempts to estimate distance modulus due to short portion of cluster main sequence we had in our disposition. Our estimations of age and reddening appeared to be in good agreement with previous ones.

SEARCH FOR VARIABLE STARS

NGC 7142 has two known variables. One of them (V582 Cep) lies out of our field of view, the other (V375 Cep) was observed successfully in V and I bands. Photometry of stars in the field of the open cluster NGC 7142 in VRI filters was performed to search for variable stars. Eleven probable variable stars were found using robust median statistics (RoMS), described by Rose & Hintz [8]. One of the stars is known as V375 Cep. The statistics is represented by the equation:

RoMS =
$$\frac{1}{N-1} \sum_{i=1}^{N} \left| \frac{m_i - \overline{m}}{\sigma_i} \right|,$$
 (1)

where (N-1) is the number of degrees of freedom, N is the number of observations, m_i is the magnitude of the *i*-th observation, \hat{m} is the median value (not the average) of N observations, and σ_i is the error per observation for a given magnitude m_i defined by an analytical error curve function.

Differential photometry was proceed for all the suspect variable stars. For this aim for each variable three comparison stars were used. The angular distance between variable and comparison star is less then 30'', magnitude difference is less then 0.5^m , rms deviation of comparison star magnitude changes from 0.01^m to 0.06^m and equals to variable's one.

The periods were determined using the WinEfK software package developed by Dr. V.P. Goranskij for Windows environment using Lafler-Kinman method. All the information about periods and types of variable stars is presented in Table 2. Some comments to the table are given below. All the lightcurves are shown in Fig. 3.

All the spectral types were roughly determined from Q-index diagram (see Fig. 1).

Object V375 Cep is one of two known variable stars in NGC 7142 field, opened by G. Crinklaw and F. D. Talbert [2]. Later R. Seeberger, R. Weinberger and R. Ziener [9] using additional observations suggested that the variable might be of W UMa type. According to our observational data the star appeared to be of EA type.

We suppose the star 1523 is of RR type due to its period, amplitude, spectral type and location on HR diagram, but it might be an eclipsing star of EW type with period of 0.58 days.

ID	ra	dec	Type	max	min	System	Period,	Sp
							$_{ m days}$	
958	21 44 54.74	$+65\ 43\ 55.3$	EA	16.13,15.50	16.53,15.90	V, I	0.9720	K0
995	$21\ 46\ 03.07$	$+65\ 43\ 59.7$	SR:	13.55, 12.30, 11.06	13.61,12.36,11,10	V, R, I	14:	
1043	21 44 13.20	$+65\ 45\ 01.3$	EB/EW	15.75, 15.15, 15.05	16.20, 15.60, 15, 50	V, R, I	0.4413	G3
1153	$21\ 44\ 55.97$	$+65\ 45\ 49.9$	SR:	15.51, 14.33, 13.75	15.71, 14.53, 13.86	V, R, I	> 20	
1233	21 44 28.43	$+65\ 46\ 36.5$	EB/EW	17.75, 16.70	18.75, 17.70	V, I	0.3303	
1400	21 43 47.85	$+65\ 48\ 22.5$	SR:	13.43, 12.16, 11.14	13.47, 12.19, 11.17	V ,R, I	20:	
1459	$21\ 44\ 29.61$	$+65\ 48\ 43.8$	EA	14.70, 14.73	15.15, 15.10	R, I	-	F5
1523	21 45 15.15	$+65\ 49\ 24.2$	RR:	15.27, 14.77, 14.83	15.37, 14.87, 14.95	V, R, I	0.2900	F0
1561	$21\ 46\ 08.90$	$+65\ 49\ 31.8$	SR:	13.30, 12.09, 11.30	13.35, 12.13, 11.33	V, R, I	13:	
1865	$21\ 43\ 52.83$	$+65\ 54\ 27.7$	SR:	14.23, 12.80, 11.68	14.35, 12.90, 11.73	V, R, I	20:	
1880	21 45 10.69	$+65\ 54\ 22.6$	SR:	13.09, 11.78, 10.81	13.14,11.83,10.84	V, R, I	>20	

Table 2: Variable stars.

CONCLUSIONS

We performed VRI photometry of 2194 stars in the field of the open cluster NGC 7142. According to its CMD and color-color diagrams we determined the log age of 9.55 and reddening $E(J-H)=0.13\pm0.05$. These results are in good agreement with the previous estimations. 11 variables were studied, 10 among them were detected for the first time, 4 variables appeared to be probable cluster members.

NGC 7142 obviously contains blue straggler stars (BSs). Our next task is to investigate high-resolution spectra of brightest BSs of the cluster. For our variable stars we intend to solve lightcurves of the eclipsing binaries we found and probably to search for low-amplitude variables with periodogram analysis.

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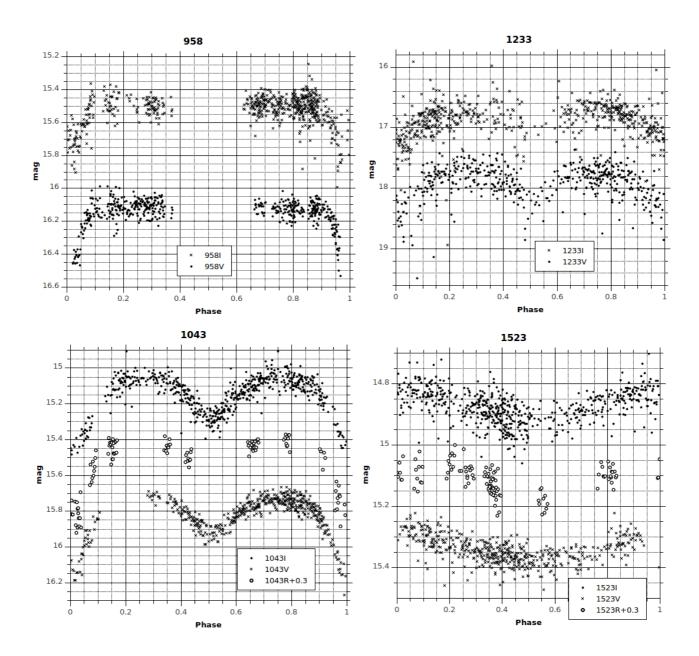


Fig. 3: Lightcurves of the short-period variable stars which periods were determined precisely.