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A new spectroscopic binary BD +38°2777 in the field of doubtful open cluster DOL–DZIM 5

Algirdas Kazlauskas [a,*], Julius Sperauskas [b], Richard P. Boyle [c]

[a] Institute of Theoretical Physics and Astronomy, Vilnius University, Goštauto 12, Vilnius LT-01108, Lithuania
[b] Vilnius University Observatory, Čiurlionio 29, Vilnius LT-03100, Lithuania
[c] Vatican Observatory Research Group, Steward Observatory, Tucson, AZ 85721, USA

HIGHLIGHTS

- ▶ We report photoelectric photometry of 13 stars in the Strömvil system.
- ▶ New radial velocity measurements of 11 stars have been obtained.
- ▶ New spectroscopic binary BD + 38 3777 has been detected.
- ▶ Main parameters of its orbit have been determined.
- ▶ It is shown that Dol–Dzim 5 is not a real open cluster.

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ABSTRACT

We present Strömvil photometry and radial-velocity measurements of the brightest ($V < 12$ mag) stars in the region of the suspected open cluster Dol–Dzim 5. The long-term radial-velocity monitoring has revealed that one of the stars, BD + 38°2777, is a spectroscopic binary star. Its orbit, with a period of $P = 541$ days, is calculated from 16 Coravel-type radial-velocity measurements. The analysis of the available astrometric, photometric and spectroscopic data has shown that reality of Dol–Dzim 5 seems unlikely.

1. Introduction

The WEBDA database[1] and the catalogue of open clusters compiled by Dias et al., 2002 contain a number of clusters named Dolidze and Dolidze-Jimsheleishvili (Dol–Dzim). The original literature sources in which these open clusters were initially reported are unreachable online; therefore it is appropriate to give here brief information on their origin.

These open clusters were identified in a spectroscopic survey initiated by Dolidze, 1960 at the Abastumani Astrophysical Observatory, which was aimed to search for objects with emission lines and stars of spectral types M, C and S. For this purpose the 70 cm Maksutov system (meniscus type) telescope, equipped with an 8 deg objective prism producing dispersions of 630 Å/mm at H_α and 90 Å/mm at 3700 Å, had been used (Kiladze, 1959). The lists containing a total of 57 star clusters are given in Dolidze, 1961a; Dolidze, 1961b; Dolidze, 1975. Twenty-two clusters in the Dolidze lists are either containing stars with emission in H_α or associated with diffuse nebulae.

A revised list of the Dolidze clusters, together with comprehensive notes on their positions, sizes and coordinates, are given by Matthias Kronberger.[2] In this list, 17 Dolidze clusters are classified as "possible" or "likely" clusters, while other stellar clusterings are marked as asterisms, associations or dubious cluster candidates.

Up to now only a small number of the Dolidze clusters have been studied for membership or their main physical parameters. For seven clusters (Dolidze 24, 25, 36, 38, 40 and 41), the members were identified by Dias et al., 2002 using proper-motion data in the TYCHO2 catalogue. For other Dolidze clusters (Dolidze 23, 25, 39,

* Corresponding author. Tel.: +370 52193264; fax: +370 52125361.
E-mail addresses: algirdas.kazlauskas@tfai.vu.lt (A. Kazlauskas), julius.sperauskas@ff.vu.lt (J. Sperauskas), rpboyle@mac.com (R.P. Boyle).

[1] http://www.univie.ac.at/webda/

[2] http://www.astro.iag.usp.br/~wilton/Dolidzelist.txt

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42), membership information (Dias et al., 2006) was based on the positions and proper motions in the UCAC2 catalogue. The existence of Dolidze 25 as a physical group is confirmed also by photometric means. Delgado et al., 2010 identified 214 candidate cluster members using *UBVRIJHK* photometry. Dolidze 39, however, was not confirmed to be a cluster from analysis by Maciejewski and Niedzielski, 2008. Their conclusion is based on the results of CCD photometry in *BV* filters, combined with JHK_s photometry and star density distribution in the vicinity and the central part of this cluster. The latest version 3.2 (January 2012) of Dias et al. catalogue contains 42 Dolidze clusters from the original list of 57 clusters. Fourteen clusters are included in the list of removed clusters and one cluster (Dolidze 7) has an entry as Berkeley 87. Eight clusters (Dolidze 21, 22, 25, 36, 38, 39, 42) have their distances and the values of reddening determined. The Webda database contains the first 47 clusters from the original list. The majority of these have no data, except for their coordinates. Only Dolidze 25, 36, 38, 42 and Dolidze 7 = Berkeley 87 have known distances, ages and values of interstellar reddening.

Another list of 11 possible clusters was given by Dolidze and Jimsheleishvili, 1966. Two of them, i.e. Nos. 5 and 8 were marked by authors as "doubtful". The first 9 clusters in their list were identified in the course of spectral classification of stars in the near-ultraviolet spectral region. These clustering of stars were suspected as clusters due to their resemblance to open clusters of type 2 (relatively small number of stars in the giant branch) according to the classification scheme proposed by Trumpler, 1930. Two clusters from this group, i.e. Dol–Dzim 1 and 8, are removed from the catalogue of Dias et al., 2002 on the basis of the study by Archinal and Hynes, 2003.

These 11 Dol–Dzim clusters were analyzed by Tadross, 2009 using the JHK_s color-magnitude diagrams (CMD) of 2MASS photometry. For all 11, ages, metallicities, distances, and values of reddening were derived by fitting color-magnitude diagrams to the theoretical isochrones. The diameters of the clusters were also estimated. In a CMD fitting procedure the exact location of the giant branch plays a crucial role. In this work, however, the giant branch was determined only by colors of a few giants, without any discussion about their membership status.

In this paper we present Strömvil photometry (Straižys et al., 1996) and radial-velocity measurements of stars down to $V \sim 12$ mag in the area of probable open cluster Dol–Dzim 5 ($\alpha(2000) = 16^h27.6^m, \delta(2000) = +38^\circ04',\ l = 60.87^\circ,\ b = +43.88^\circ$) and discuss the reality of the cluster. We also give the orbital parameters for a new spectroscopic binary star, BD $+38^\circ2777$, detected among the studied stars.

2. Photometry and spectral classification

Photoelectric photometry of 13 brightest stars both in the Vilnius and in the Strömgren systems was obtained with a two-channel photometer on the 1.5 m telescope of the Steward Observatory on Mt. Lemmon in February–March 2003. The instrumental setup, as well as the technique of transformations of the observations to the standard systems was described in detail in Kazlauskas et al., 2005.

The results of the photometry are given in Table 1, which contains the mean magnitudes and color-indices in the Vilnius and Strömgren systems. The columns give the following information: star number in the identification chart (see Fig.1), V magnitude, color indices $U-V,\ P-V,\ X-V,\ Y-V,\ Z-V,\ V-S,\ b-y,\ m_1,\ c_1$ and the number of observations n. The corresponding overall standard errors in magnitude V and color indices, with the contribution from the transformations to the standard system incorporated, are given in the second line of each entry.

The photometric spectral classification of the observed 13 stars was performed by several methods developed for the Vilnius photometric system. All these methods are based on a search for stars analogous to the observed star in the multidimensional space of reddening-free Q-parameters and color indices of standard stars with well-known spectral types and luminosities calibrated according to the MK types. When the closest standard stars are found, then their mean values of spectral types, M_V and color-excess $E(Y-V)$ are accepted as the result of classification. The search procedure relies on a criterion of minimal squared distance in the Q-parameter and/or color-index space. The methods applied differ only in the way how the bank of standard values is defined (averaged Qs and/or color indices or Qs and color indices of real stars

Table 1
The results of photoelectric photometry in the Strömvil system.

No.	V	$U-V$	$P-V$	$X-V$	$Y-V$	$Z-V$	$V-S$	$b-y$	m_1	c_1	n
1	10.403	2.281	1.761	1.160	0.482	0.170	0.471	0.311	0.458	0.181	2
	0.013	0.013	0.010	0.010	0.005	0.006	0.008	0.008	0.020	0.015	
2	11.217	4.795	4.074	2.780	0.994	0.484	0.960	0.837	0.401	0.668	3
	0.012	0.012	0.011	0.010	0.005	0.006	0.009	0.009	0.019	0.016	
3	8.763	5.672	4.656	3.288	1.265	0.494	1.214	1.115	0.719	0.528	3
	0.014	0.011	0.011	0.010	0.005	0.006	0.008	0.009	0.018	0.015	
4	11.944	2.152	1.689	1.152	0.492	0.174	0.491	0.321	0.338	0.161	2
	0.012	0.012	0.012	0.010	0.013	0.008	0.010	0.009	0.023	0.017	
6	10.197	2.562	2.129	1.429	0.568	0.220	0.553	0.400	0.324	0.254	3
	0.012	0.011	0.010	0.010	0.007	0.007	0.008	0.009	0.019	0.015	
7	9.297	4.831	4.135	2.807	0.988	0.462	0.930	0.831	0.372	0.712	3
	0.013	0.012	0.010	0.010	0.005	0.006	0.008	0.009	0.018	0.015	
8	10.637	3.933	3.331	2.229	0.823	0.361	0.791	0.662	0.399	0.504	3
	0.012	0.011	0.011	0.010	0.005	0.007	0.009	0.009	0.019	0.016	
9	10.558	2.234	1.747	1.157	0.482	0.180	0.466	0.311	0.405	0.184	3
	0.013	0.011	0.010	0.010	0.005	0.006	0.009	0.009	0.018	0.015	
10	11.467	2.169	1.696	1.157	0.491	0.178	0.498	0.320	0.336	0.171	3
	0.012	0.011	0.010	0.010	0.008	0.007	0.010	0.009	0.019	0.016	
11	11.945	2.446	1.962	1.338	0.540	0.204	0.548	0.371	0.364	0.218	3
	0.015	0.012	0.011	0.011	0.007	0.007	0.009	0.009	0.019	0.016	
12	10.391	3.304	2.790	1.882	0.711	0.304	0.713	0.546	0.368	0.379	3
	0.012	0.011	0.010	0.011	0.005	0.006	0.009	0.009	0.018	0.015	
13	11.276	2.555	2.118	1.449	0.584	0.231	0.578	0.415	0.298	0.240	2
	0.012	0.011	0.010	0.010	0.005	0.006	0.008	0.009	0.018	0.015	
14	10.003	2.231	1.723	1.148	0.490	0.178	0.474	0.319	0.421	0.163	2
	0.017	0.012	0.010	0.010	0.006	0.008	0.010	0.009	0.019	0.016	

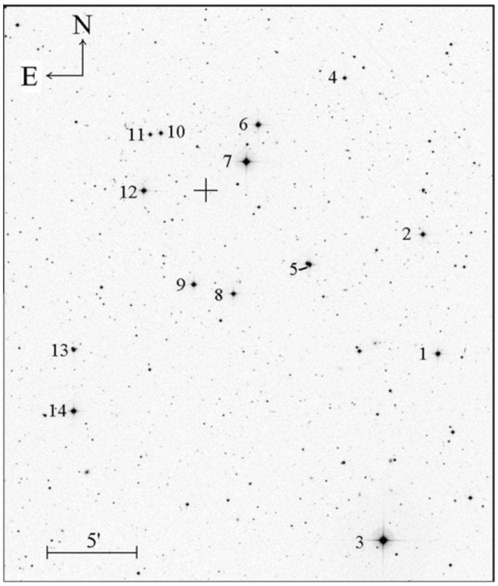

Fig. 1. Cross marks the center of the cluster $\alpha(2000) = 16^h27^m24^s$, $\delta(2000) = +38^\circ04'$ given in the Webda. The image scale is shown at the bottom left.

with known parameters). A detailed description of these methods can be found in Zdanavičius et al., 2010. The spectral types obtained by any of the methods used show a good coincidence, not exceeding 1–2 spectral subclasses. The typical errors in absolute magnitudes may amount to ±0.25 mag for dwarfs and ±0.5 mag for giants, which lead to the uncertainty in distances within 25%. The interstellar reddening of stars does not exceed $E(Y-V) = 0.015$ mag, which corresponds to $E(B-V) = 0.02$ and is in agreement with the value of interstellar extinction in this direction derived by Schlegel et al., 1998.

Table 2 presents the results of the spectral classification along with the identification numbers used in this paper, BD or GSC numbers and the coordinates of the stars. The photometric metallicities (column $[Fe/H]_{\rm V}$ in Table 2) were obtained from the revised calibration of the Vilnius photometric system, elaborated by Bartašiūtė et al., 2012. According to the authors, the errors of this calibration do not exceed ±0.15 dex. We also estimated the metallicities by using the *uvby* photometric system calibrations of Nordström et al., 2004 (column $[Fe/H]_{\rm N}$) and Schuster and Nissen, 1989 (column $[Fe/H]_{\rm SN}$), valid for F and G type stars. The corresponding errors of their calibration equations are ±0.10 dex for F-type stars and ±0.12 dex for G-stars in Nordström et al. (2004) and 0.16 dex both for F and G type stars in Schuster and Nissen, 1989. It should be noted, that metallicity of stars, derived by using the Vilnius system calibration is systematically lower than both calibrations of the Strömgren system. However, taking into account the estimated errors of calibrations, all three methods show similar results, indicating the metallicity near to solar.

Table 3
Radial velocities of stars in situ toward the open cluster Dol–Dzim 5

Id	V_r, km/s	e, km/s	N
1	−15.8	0.6	2
2	−9.0	0.1	11
3	7.0	0.4	2
5	18.1	0.4	2
7	−34.6	0.3	2
8	−9.7	0.6	3
9	7.8	0.8	2
10	21.4	0.6	2
12	−10.6	0.4	2
13	−25.3	0.4	2
14	−50.8	0.5	2

3. Radial velocities

Radial velocities of the stars were measured with the Coravel-type spectrometer of the Vilnius University Observatory and the 1.65 m telescope of the Molėtai Observatory. The spectrometer and the techniques of measurements and data reduction are described in Upgren et al., 2002. Most of the observations were obtained during two observing runs – in 2003 and 2008. Separated in time observations enabled us to identify stars with variable radial velocities. Among measured stars only BD $+38^\circ2777$ revealed itself as a spectroscopic binary.

The weighted mean radial velocities, $< V_{\rm r} >$, their standard errors, and number of observations are given in Table 3.

As we can see from the Fig. 2, radial velocities of the measured stars are spread over a wide interval: from -51 to +21 km/s. Only three stars, Nos. 2, 8, and 12, are clustering in a narrow interval of velocities, -10.6 to -9.0 km/s. However, due to their rather different proper motions given in TYCHO-2 and photometric distances (Table 2), these stars cannot be treated as physically related.

4. Spectroscopic binary star BD $+38^\circ$ 2777

In the years 2003–2010, 16 radial velocity measurements were obtained for BD $+38^\circ2777$, a newly detected spectroscopic binary star. Its individual radial velocities are given in Table 4, together with moments of observations, phases and residuals O–C calculated with the orbital elements (Table 5).

All of the radial velocities have been weighted equally in the solution of the orbit. Fig. 3 shows the radial velocity curve with the individual measurements plotted.

In the Vilnius photometric system, BD $+38^\circ2777$ is classified as a normal star of spectral type G5 V. All its color indices coincide

Table 2
Identification and the results of photometric classification

No.	BD/GSC	RA2000	DEC2000	Sp. type	M_V	E (Y-V)	R (pc)	$[Fe/H]_V$	$[Fe/H]_N$	$[Fe/H]_{SN}$
1	GSC 03062–01468	16 26 23.8	+37 55 34	F7 IV	2.5	0.015	370	+0.14	+0.23	+0.31
2	GSC 03062–01292	16 26 27.6	+38 01 45	K3 III	0.5	0.015	1350	−0.31		
3	BD +38°2775	16 26 38.2	+37 45 54	M3 III	−0.4	0.015	660	−0.10		
4	GSC 03063–01860	16 26 48.3	+38 09 53	F8 V	3.9	0.015	400	−0.34	+0.01	−0.01
6	BD +38°2777	16 27 10.9	+38 07 25	G5 V	5.0	0.000	110	+0.16	+0.33	+0.27
7	BD +38°2778	16 27 14.1	+38 05 31	K3 III	0.6	0.015	530	−0.10		
8	BD +38°2779	16 27 17.4	+37 58 40	K1 IV	2.1	0.015	500	0.00		
9	BD +38°2780	16 27 27.9	+37 59 10	F6 V	3.7	0.010	230	+0.08	+0.24	+0.32
10	GSC 03063–02073	16 27 36.5	+38 06 59	F8 V	3.8	0.015	330	−0.31	+0.12	+0.14
11	GSC 03063–02186	16 27 39.3	+38 06 57	G1 V	4.5	0.000	310	+0.06	+0.47	+0.34
12	BD +38 2781	16 27 41.0	+38 04 01	K0 IV	3.1	0.015	280	−0.23	+0.20	+0.04
13	GSC 03063–01804	16 27 59.4	+37 55 47	G4 V	5.0	0.010	180	−0.16	+0.00	−0.01
14	GSC 03063–01733	16 27 59.4	+37 52 36	F7 V	3.5	0.015	190	−0.07	+0.07	+0.07

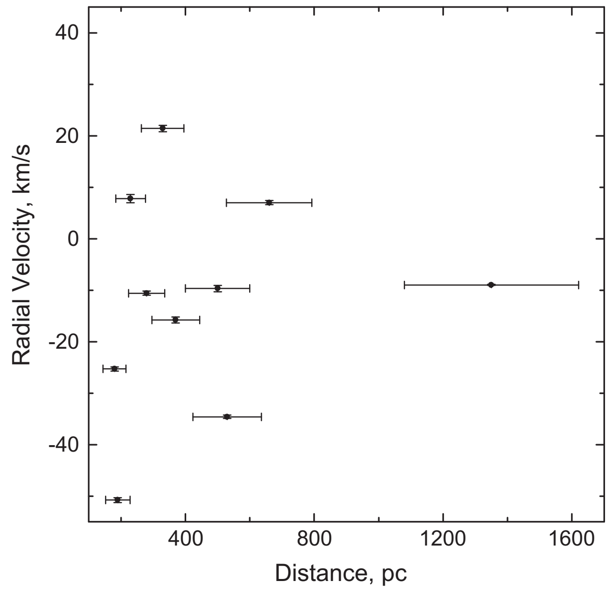

Fig. 2. Plot of radial velocities versus distances for stars in situ of Dol–Dzim 5.

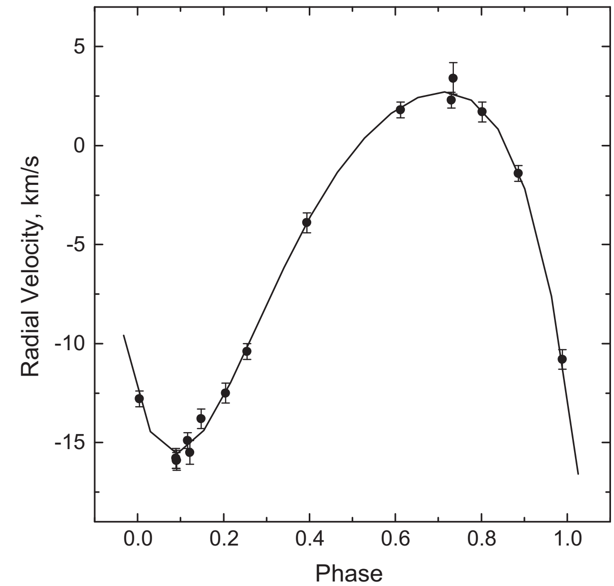

Fig. 3. Radial velocity curve of BD +38°2777.

Table 4
Individual radial velocities, phases and residuals of the spectroscopic binary star BD +38°2777.

JD-240000	Phase	$< V_r >$, km/s	O–C, km/s	e, km/s
52767.388	0.735	3.4	0.59	0.8
54582.563	0.089	−15.8	−0.05	0.5
54583.487	0.091	−15.9	−0.15	0.5
54600.441	0.122	−15.5	−0.23	0.6
54614.393	0.148	−13.8	0.69	0.5
54645.422	0.205	−12.5	−0.38	0.5
54672.404	0.255	−10.4	−0.53	0.4
54747.203	0.394	−3.9	0.35	0.5
54865.613	0.612	1.8	0.10	0.4
54929.493	0.730	2.3	−0.52	0.4
54968.439	0.802	1.7	−0.29	0.5
55013.431	0.886	−1.4	0.32	0.4
55069.344	0.989	−10.8	0.28	0.5
55077.334	0.004	−12.8	−0.43	0.4
55124.180	0.090	−15.9	−0.15	0.4
55138.180	0.116	−14.9	0.52	0.4

Table 5
Orbital elements of BD +38°2777.

Orbital period	$P = 541 \pm 5$ d
Center-of-mass velocity	$V_o = -4.9 \pm 0.2$ km/s
Half-amplitude	$K = 9.3 \pm 0.1$ km/s
Eccentricity	$e = 0.27 \pm 0.02$
Longitude of periastron	$w = 127 \pm 3$ deg
Date of conjunction	$T(conj) = 2455075 \pm 4$ JD
Projected semimajor axis	$asin(i) = (0.664 \pm 0.008)E+08$ km
Function of the mass	$f(m) = 0.040 + 0.002 M_\odot$
Standard deviations of residuals	$\sigma(O - C) = 0.4$ km/s

with the indices of typical G5 V stars within 0.02 mag. A comparable spectral type, G2 V, is also given for this star in Ofek, 2008 catalogue, where classifications are based on V_T, B_T and JHK magnitudes. Thus we may conclude that the secondary component is much fainter than the primary and it has no appreciable influence on the combined light or combined spectrum. Such a conclusion is also confirmed by the fact that we do not detect any additional dip in the cross-correlation curve due to the secondary component. Assuming $1M_\odot$ for the primary's mass according to its spectral type and applying the binary mass function we obtain for the secondary a minimal mass of $0.44M_\odot$. It follows that the secondary should be of spectral type $\sim$ M2, if on the main sequence, and $\Delta(M_V) < 5$ mag.

5. Reality of the cluster

The discrepancy in distances and radial velocities presented in Tables 2 and 3 indicates that the observed stars do not constitute a physically related group. On the other hand, Tadross, 2009 derived the distance and age of the cluster Dol–Dzim 5 on the basis of 2MASS photometry (Skrutskie et al., 2006) by applying color-magnitude filters and isochrones. Thus we cannot reject the possibility that the cluster is real, but the stars observed by us are either foreground or background stars. Hence it is worth to examine the reality of the cluster more thoroughly. For this purpose, we have combined the results from star counts, photometry, radial velocities and proper motions.

5.1. Star counts and spatial distribution

For star counts we have used 2MASS (Skrutskie et al., 2006) catalogue, down to J <16.5 mag, taking into account only stars with $\sigma_J < 0.1$ mag. As we can see in Fig. 1, the field is very sparse, without any noticeable enhancement of star number density. The center of the cluster, marked by cross in Fig. 1, has obviously been defined as an average of the positions of eight comparatively bright stars (Nos. 5, 6, 7, 8, 9, 10, 11, 12). Fig. 4 shows the surface density of stars of different J magnitudes as a function of the angular distance from the center. There are no stars in the central part up to the angular distance r = 1.5 arcmin from the center. Bright stars with J <13 mag show an insignificant local enhancement in the stellar density at the distance r = 2.5–3 arcmin from the center, which is evidently produced by the above-mentioned group of stars. The fainter stars show several local enhancements, slightly exceeding the errors of control field, the most notable of which seen in the annulus between r = 4.5 and 5.5 arcmin. However, we do not see any clustering of the faintest stars toward the center.

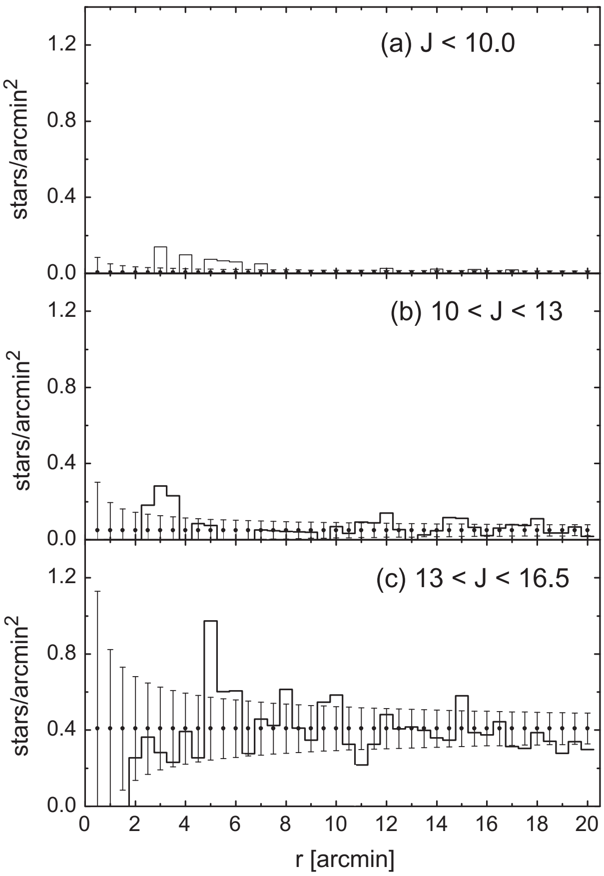

Fig. 4. Surface density of the stars, measured by counts in 0.5 arcmin annuli centered on $\alpha(2000) = 16^h27^m24^s$, $\delta(2000) = +38^\circ04'$, as a function of the angular distance from the center. Dots with error bars show the mean surface density in the surrounding control field in the annulus with r = 20–50 arcmin around the center and the expected 1 σ range for each distance bin.

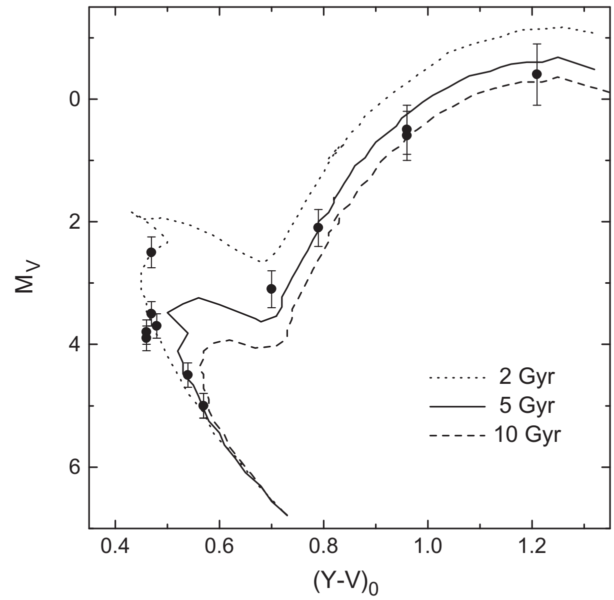

Fig. 5. HR diagram of the observed stars in the Vilnius photometric system. The dotted, solid and dashed lines show the Padova isochrones of 2, 5 and 10 Gyr, respectively.

Therefore, as probable cluster members, we should consider only stars brighter than $J < 13$ mag.

5.2. Photometry

As Table 2 shows, the spread in the distances of 13 brightest stars in the field is of the factor of 10. Eliminating the most deviating stars we still have the spread of the factor of 3, which exceeds obviously the typical ±25% error of photometric distance determinations. Fig. 5 shows the HR diagram of the observed stars in the Vilnius photometric system, with the absolute magnitudes M_V plotted versus color index $Y - V$ corrected for interstellar reddening (Table 2). We also plotted in the same diagram three isochrones of solar metallicity (Z = 0.02) for ages of 2, 5 and 10 Gyr. The isochrones are from the Padova models, transformed to the Vilnius photometric system by Bressan and Tautvaišienė, 1996. In the paper of Bartašiūtė et al., 2007 it was shown that those isochrones need some zero-point corrections. We applied to the isochrones a zero-point correction of $\Delta(Y - V) = +0.02$ mag. It is evident that we are not able to fit a single isochrone to the positions of all stars in the diagram. This gives further support to the conclusion that the brightest stars in the area do not form a physical group.

To examine the fainter stars, we have used the 2MASS photometry and applied similar algorithm of removing the field stars, as proposed by Mighell et al., 1996 and developed in a series of papers of Bonatto and Bica (see, e.g.,Bonatto and Bica, 2007;Bonatto and Bica, 2009;Bica and Bonatto, 2011). To construct the decontamined CMD we defined the offset field as a ring with an inner radius of 20 arcmin and an outer radius of 50 arcmin. Then the CMDs of probable cluster area (the circle with a radius of 10 arcmin) and of the offset field were divided into 3-dimensional bins of ΔJ = 1 mag, $\Delta(J - H)$ = 0.2 mag and $\Delta(J - K_S)$ = 0.2 mag. The algorithm provides a possibility to choose the size of bins. Quite wide bins in our case were chosen due to the sparsity of stars in the investigated field. The number of stars in each bin of the CMD of the offset field was multiplied by the ratio of cluster to offset areas. Then the cleaned CMD of the cluster field was constructed by randomly subtracting the corresponding number of stars from each bin in the CMD. This procedure was repeated many times (up to 100) with different seeds to the random number generator. The list of cluster stars was composed from stars which have "survived" after all subtractions more times than others. Fig. 6 shows the original and decontaminated CMDs along with the CMD of the control field. As we can see, the decontamination procedure in the field of Dol–Dzim 5 did not affect seriously the original CMD. On the decontaminated CMD (Fig. 6c) we also plotted the same isochrone ($Z = 0.019$, $T = 2$ Gyr) from the Padova database[3] as in the paper of Tadross, 2009. The solid line shows the isochrone adjusted to the same value of distance modulus as in that paper ($m - M = 9.8$ mag), while the dashed line is the same isochrone shifted by the distance modulus $m - M = 8.0$, which corresponds to some clumping of bright stars around the distance of 400 pc (Table 2). A small reddening correction $E(J - K_S) = 0.01$ mag was applied, assuming R_V = 3.1 and $E(B - V)$ = 0.02 and using the 2MASS extinction relations A_J/A_V = 0.276, A_H/A_V = 0.176, A_J/A_{K_S} = 0.118 and $A_J = 2.76E(J - H)$ given by Dutra et al., 2002. Fig. 6b shows the diagram for our control annular field of equal area at the angular distance R = 20–22.4 arcmin from the center. Only stars with J, H and K errors lower than 0.1 mag were used in all diagrams. Open circles in Fig. 6c mark the stars for which Strömvil photometry has been obtained.

[3] <http://pleiadi.pd.astro.it/>

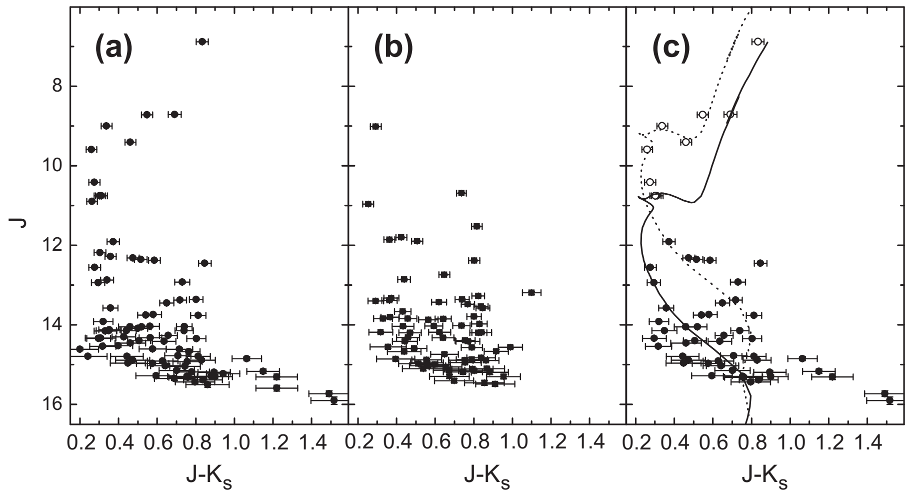

Fig. 6. The color-magnitude diagrams in the region of Dol–Dzim 5. (a) CM diagram of stars in 10 arcmin circular area. (b) CMD of stars in a surrounding control field of equal area. (c) Decontaminated CMD. Open circles are stars, observed in this investigation. The solid line shows the isochrone of 2 Gyr (Z = 0.019), shifted by distance modulus $m - M = 9.8$ mag. Dashed line is the same isochrone shifted by $m - M = 8.0$ mag.

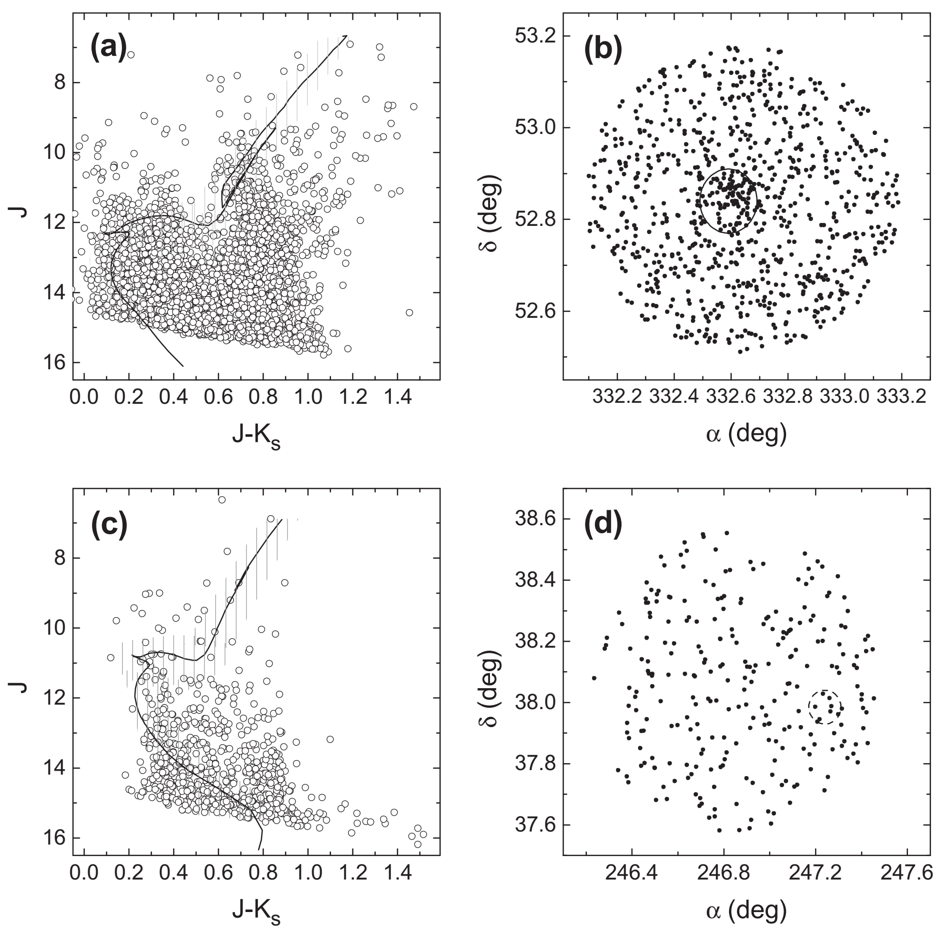

Fig. 7. The color-magnitude diagrams and distribution of stars laying near the fitted isochrone (see text) over the field. (a) CMD of the stars in 20 arcmin circular area around the cluster IC 1434. The isochrone of 800 Myr is corrected for the interstellar extinction A_V = 0.4 mag and adjusted to the distance 2.6 kpc. (b) distribution of stars laying in a shaded area around the isochrone. The circle marks the most likely clustering. (c) CMD of the stars in 30 arcmin circular area around the cluster Dol–Dzim 5. The isochrone of 2 Gyr is corrected for the interstellar extinction A_V = 0.06 mag and adjusted to the distance 900 pc. (d) same as b, but for cluster Dol–Dzim 5.

At the first glance the supposed cluster area is different from the one of the control field. In Fig. 6c we can easily discern a giant branch, and the group of stars in the upper part of the main sequence almost absent in the control field. However we already know that the red giants and the stars in the upper part of the main sequence are widely spread over the distance and do not share a

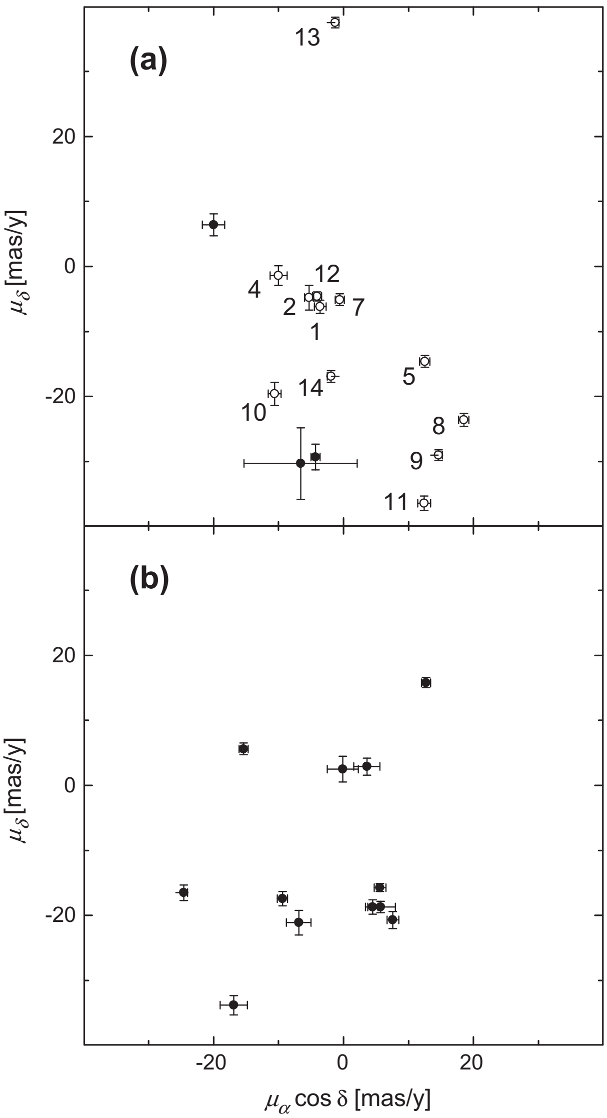

Fig. 8. Proper motions in the region of Dol–Dzim 5 from Tycho-2 catalogue. (a) PM of stars in 15 arcmin circular area. (b) PM of stars in an annulus, bounded by angular radiuses r1 = 20 arcmin, r2 = 30 arcmin.

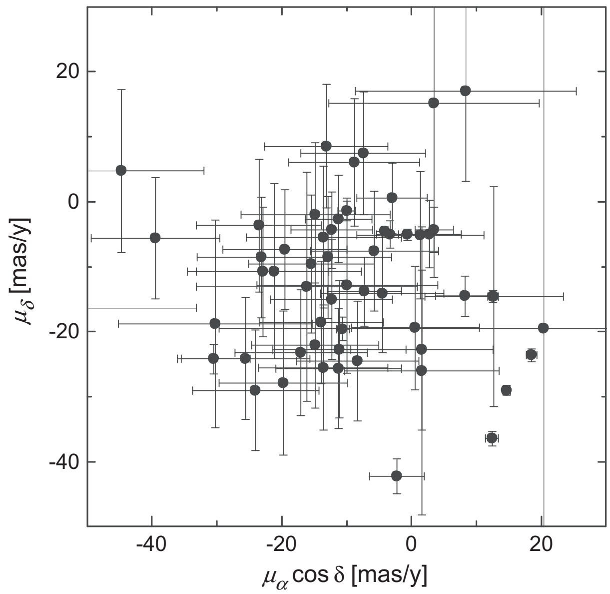

Fig. 9. Proper motions of stars in 10 arcmin circular area from UCAC3 catalogue.

common radial velocity. We can expect that the stars around the best fit isochrone should show a spatial clustering if the cluster is real. To test this, we decided to use the Kuldorffs spatial scan statistic (Kulldorff, 1997) and the SaTScan[4] software. Once we know the members of the cluster, the spatial scan statistic allows us to evaluate the statistical significance of the cluster and to define its center. Let as assume that all stars in the investigated area, which lay near the fitted isochrone, can be the members of the cluster while all other stars are nonmembers. Each star is either member or not, and we can use the probability model of Bernoulli. To test how this algorithm works, we have chosen the open cluster IC1434, recently investigated by Bica and Bonatto, 2011. We downloaded 2MASS data in a circular area of radius R = 20 arcmin around the cluster center with coordinates $\alpha(2000) = 22^h10^m30^s$, $\delta(2000) = +52^\circ50.5'$ and plotted the CMD for stars with J, H and K errors less than 0.1 mag together with Padova (Girardi et al., 2002) isochrone of 800 Myr, corrected for the interstellar extinction A_V = 0.4 mag and adjusted to the distance 2.6 kpc (Fig. 7a). Then all stars lying in the CMD around the isochrone (taking into account the photometric uncertainties and the location of probable sequence of binary stars; shaded area in Fig. 7a.) were assumed as 'cases' and all the other stars as 'controls' in the input of the SaTScan software. We applied in our analysis the circular windows centered on each star. The result has shown that the most likely cluster of angular size R = 4 arcmin is centered at $\alpha(2000) = 22^h10^m21^s$, $\delta(2000) = +52^\circ49.9'$ with a very low $(3 * 10^{-8})$ p-value. The coordinates are slightly different from those given in the WEBDA database as well as from those given by Bica and Bonatto, 2011, $\alpha(2000) = 22^h10^m33^s$, $\delta(2000) = +52^\circ50.6'$ (we made no attempts to redefine here the cluster coordinates). The low p-value shows that clustering is statisticaly significant at a very high level of confidence. Fig. 7b shows the distribution of 'cases' over the field and the most likely size and location of the cluster.

The same approach was applied also for the cluster Dol–Dzim 5. To construct the CMD we used a larger field, with R = 30 arcmin around the cluster center. We started from the isochrone adjusted to a distance of 900 pc, shown in Fig. 7c, and varied distances down to 400 pc. The maximal search radius was set to 10 arcmin. In all cases, the p-values of most likely clusters were found to be near 1, meaning that we do not observe a statisticaly significant clustering. The lowest p-value, equal to p = 0.81, was found for a cluster of radius R = 6.7 arcmin and for the isochrone adjusted to a distance of 400 pc. This is shown in Fig. 7d, together with the distribution of 'cases' over the field. Therefore, we can conclude that the reality of the cluster in the area investigated seems unlikely.

5.3. Proper motions

Tycho-2 star catalogue (Hog et al., 2000) contains 16 stars in the circular area with angular radius of r = 15 arcmin. The surrounding annular field of greater area, bounded by r_1 = 20, r_2 = 30 arcmin, contains only 13 Tycho-2 stars. Their vector point plot is shown in Fig. 8. Both diagrams demonstrate similar spread in proper motions. Only five stars, i.e. Nos. 1, 2, 7, 12 and 4 have similar tangential movements, but as we have shown their distances

[4] http://www.satscan.org/. $SaTScan^{TM}$ is a trademark of Martin Kulldorff. The $SatScan^{TM}$ software was developed under the joint auspices of (i) Martin Kulldorff, (ii) the National Cancer Institute, and (iii) Farzad Motashari of the New York City Department of Health and Menthal Hygiene.

[5] http://viz er.u-strasbg.fr/viz bin/VizieR?-source = II/246

and/or radial velocities are different. The small number of stars with Tycho proper motions does not allow to draw statistical inferences from the data, thus we have used the Vizier[5] service to download proper motions from the UCAC3 catalogue (Zacharias et al., 2010). The vector point diagram of the central part of the field is shown in Fig. 9. After rejecting outliers the mean values of proper motions from UCAC3 in the annular area within $R = 20–30$ arcmin are, $\mu_\alpha = -9.7$ and $\mu_\delta = -5.7$ [mas/yr], with corresponding standard deviations of 10.9 and 12.7 [mas/yr] respectively, while in the central part of the field with $R = 10$ arcmin $\mu_\alpha = -8.8 \pm 13.6$ and $\mu_\delta = -12.4 \pm 12.3$ [mas/yr]. Are those differences significant and is there any clustering of stars with similar proper motions? To answer this question we, again, used the Kulldorfs spatial scan statistic. This time we assumed that all stars with proper motions in the range $\mu_\alpha = -8.8 \pm 9$ and $\mu_\delta = -12.4 \pm 9$ [mas/yr] can be regarded as possible cluster stars. The ranges of the proper motions were chosen taking into account the mean errors given in UCAC3. The spatial scan analysis again does not show any significant clustering. The most likely cluster with the p-value $p = 0.96$ has a radius of $R = 2.5$ arcmin and consists of only 4 stars. We can conclude that statistical analysis of proper motions does not, too, support the reality of the cluster.

6. Conclusions

In this paper we have presented the new photometry and radial velocities of several brightest stars in the region of the suspected open cluster Dol–Dzim 5. The photometric spectral classification and distances of the observed stars have been determined. The metallicity of the stars in the investigated field has been found slightly higher than solar.

The new spectroscopic binary star BD $+38^\circ 2777$ has been detected and the main parameters of the orbit have been determined.

We also examined the reality of the open cluster Dol–Dzim 5, by using available photometric, spectroscopic and astrometric information. We have shown, that this concentration of stars can hardly be regarded as a physical ensemble and most likely is an asterism of several bright stars.

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