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NEW PHOTOMETRY OF BLUE STRAGGLERS IN FOUR GALACTIC OPEN CLUSTERS

TAŞ, GÜNAY; EVREN, SERDAR; ÖZDARCAN, ORKUN; DAL, HASAN A.; SİPAHİ, ESİN

Ege University Observatory, 35100 Bornova - İzmir - TURKEY

Blue straggler stars are very interesting subjects according to the stellar evolution theory. The appearance of the stars is not expected on the main-sequence and on the bluer side of the cluster turn-off point according to the standard evolution theory. Although there are some scenarios that have tried to clarify their locations on the H-R diagram, their origins are still considered as uncertain. In this context, the variation mechanisms of blue stragglers can provide a clue to explain their existence and to derive their physical parameters. Hrivnak (1977), Lapasset and Ahumada (1996), Mateo (1993), Maitzen et al. (1981) can be given as example studies to such attempts. The locations of stars in color-magnitude and color-color diagrams are significant to determine the photometrical cluster membership probability of the stars but a more accurate photometry is needed. Hence, we initiated an observation program for blue straggler stars of four galactic open clusters. The observations were carried out with a 48-cm Cassegrain telescope equipped with a three-channel photometer, using broad-band Johnson UBV filters, at Ege University Observatory during the 2006-2007 observing season. The blue straggler stars, which catalogued in WEBDA database for four open clusters, namely IC 4725, Melotte 111, NGC 1342 and NGC 6871, were observed with the comparison stars chosen from same clusters. The observations were reduced from the effects of atmospheric extinction; and then heliocentric corrections to the observing times were applied. The standard stars with appropriate color and brightness, taken from the lists of Landolt (1992) and Harmanec et al. (1994), were used for transformation to the standard system. The galactic and equatorial coordinates (from SIMBAD) and $E(B-V)$ color excesses (from WEBDA) of the four open clusters can be seen in Table 1.

Table 1. Coordinates and $B-V$ color excesses of the four open clusters.

	Galactic coordinates		Equatorial coordinates		
Cluster	l	b	RA (2000)	DEC (2000)	$E(B-V)$
	(°)	(°)	(h m)	(° ′)	(mag)
IC 4725	13.69	−04.42	18 32	−19 07	0.476
Melotte 111	222.51	+83.40	12 22	+25 50	0.013
NGC 1342	155.19	−15.12	03 33	+37 25	0.319
NGC 6871	72.65	+02.05	20 06	+35 47	0.443

We determined the interstellar reddening in the line of sight by the color-color diagram. The estimations of color excesses in $U-B$ and $B-V$ were made by using the sliding fit method and adopting the slope of the reddening line as 0.72. The results for both blue stragglers and the comparison stars are listed in Table 2. 'BS' in the fourth column (Star type) denotes blue straggler candidates listed in the WEBDA database.

Table 2. New photoelectric photometry of blue stragglers and comparison stars in four galactic open clusters.

Cluster	WEBDA No.	HD/BD No.	Star type	V (mag)	$B-V$ (mag)	$U-B$ (mag)	$E(B-V)$ (mag)	$E(U-B)$ (mag)
NGC1342	1	21773		8.490 (6)	0.416 (10)	-0.133 (13)	0.59	0.43
NGC1342	2	21728	BS	8.815 (5)	0.235 (10)	-0.142 (13)	0.35	0.26
NGC1342	3	21785	BS	9.273 (5)	0.247 (8)	0.141 (10)	0.27	0.20
NGC1342	4	275501		9.362 (6)	1.214 (11)	1.108 (16)	0.34	0.25
NGC1342	6	275509		9.652 (8)	1.109 (12)	0.895 (20)	0.28	0.20
NGC1342	7	275507		10.160 (6)	1.123 (11)	0.824 (19)	0.34	0.24
NGC1342	8	275510		10.356 (5)	0.324 (10)	0.203 (17)	0.35	0.26
NGC1342	10	275502		10.719 (7)	0.430 (11)	0.331 (17)	0.29	0.21
NGC1342	11	275508		10.669 (7)	0.390 (9)	0.224 (11)	0.20	0.14
NGC1342		275495		9.364 (5)	0.446 (9)	-0.070 (10)	0.60	0.44
NGC 6871	4	190864	BS	7.764 (4)	0.155 (9)	-0.809 (10)	0.48	0.34
NGC 6871	5	227634	BS	7.923 (9)	0.203 (14)	-0.676 (11)	0.49	0.35
NGC 6871	7	227586	BS	8.803 (6)	0.158 (11)	-0.694 (14)	0.45	0.32
NGC 6871	8	+35° 3956	BS	8.833 (6)	0.165 (15)	-0.627 (18)	0.43	0.31
NGC 6871	1163	227767		8.871 (3)	0.016 (8)	-0.816 (11)	0.31	0.22
NGC 6871	1866	191201		7.257 (4)	0.110 (9)	-0.808 (10)	0.43	0.31
Melotte 111	89	107655		6.243 (6)	0.009 (10)	-0.010 (11)	0.04	0.03
Melotte 111	136	108449		8.271 (7)	0.263 (11)	0.043 (16)	0.34	0.24
Melotte 111	139	108486		6.684 (3)	0.170 (9)	0.101 (12)	0.20	0.14
Melotte 111	146	108662	BS	5.311 (3)	-0.020 (8)	-0.150 (10)	0.05	0.03
IC 4725	6	-19° 5032		9.553 (7)	0.192 (11)	-0.140 (12)	0.31	0.22
IC 4725	50	170682	BS	7.907 (8)	0.290 (19)	-0.071 (23)	0.41	0.29
IC 4725	91	170719	BS	8.060 (12)	0.254 (20)	-0.056 (22)	0.36	0.26
IC 4725	97	-19° 5044	BS	8.724 (15)	0.320 (22)	-0.056 (21)	0.44	0.32
IC 4725	163	170835	BS	8.765 (11)	0.200 (16)	-0.480 (18)	0.43	0.31
IC 4725	167	170836	BS	8.952 (12)	0.267 (19)	-0.120 (24)	0.40	0.29
IC 4725	233	170763		8.948 (5)	0.261 (8)	-0.028 (10)	0.36	0.26

Ahumada and Lapasset (2007) suggested new criteria to select the blue straggler stars in published data in WEBDA database; and accordingly, they excluded the stars NGC 1342 1 and 10. Both stars are also listed in Table 2 to present their new photometry. On the other hand, NGC 1342 4 (HD 275501) is tabulated by its photometric values, using Ahumada and Lapasset (2007)'s study, as $V = 9\overset{\mathrm{m}}{.}21$, $B-V = 0\overset{\mathrm{m}}{.}24$, $U-B = 0\overset{\mathrm{m}}{.}17$. The literature related to this star (Hoag et al. 1961, Jennens and Helfer 1975, Francic 1989, Svolopoulos 1961, Bersier 1996, Pena et al. 1994) and our observations showed that HD 275501 is a late type star. It is thought that there is a misprint; and the values mentioned above for this star were similar to those of NGC 1342 3. NGC 1342 3 is believed to be wrongly labeled as NGC 1342 4 in the catalogue of Ahumada and Lapasset (2007) since its location on the H-R diagram was more appropriate to be a blue straggler candidate. Thus, NGC 1342 3 was labeled as blue straggler star in Table 2. The means of the color excesses listed in Table 2 were calculated for each cluster and then adopted

as cluster's color excess. NGC 1342 1, on the other hand, was excluded since its color excesses have a very different value than other blue stragglers in the same cluster. This can be a photometric evidence for NGC 1342 1 that it may not be a member of the cluster. Consequently, we determined $E(B-V)$ reddenings of 0.40, 0.33, 0.46, and 0.05 mag for the clusters IC 4725, NGC 1342, NGC 6871, and Melotte 111, respectively.

The photometry of stars listed in Table 2 were checked for variability. As for the long-term observations of the blue stragglers included in this study; we detected that one of them, namely HD 21728, showed light variations.

Although HD 21728 has been classified as a chemically peculiar star (e.g. Svolopoulos 1961, Young and Martin 1973, Abt 1985, Renson 1992), its photometric variation was not identified up to now. We found a light variation with a period of 5.340 days, using the Phase Dispersion Minimization Technique of PERANSO period analysis program, for the star. The amplitude of the variation was 0.04 and 0.05 mag in B and V filters, respectively. We calculated the phases of the light and color curves presented in Figure 1 using the following light elements:

$$\mathrm{HJD} = 2\,454\,048.2562 + 5\overset{\mathrm{d}}{.}340(28) \times \mathrm{E},$$

where $\mathrm{T_0}$ is the time of first observation point and P is the period determined from period analysis of V data. The star's light curve has asymmetric shape, while its color curve does not establish a clear variation as can be seen from Figure 1. It is known that the light curve shapes of the chemically peculiar stars can change in different filters (e.g. Maitzen 1989, Adelman 1997). The determination of physical parameters of blue stragglers is significant to test their formation scenarios and to comprehend their origin. Consequently, their photometric or spectral variability is a fairly useful tool. The magnetic peculiar stars, which are member of cluster, are also very valuable objects to study their evolution (North et al. 2008). In this context, additional multicolor broad and intermediate band photometry of HD 21728 is considered as necessary for future studies.

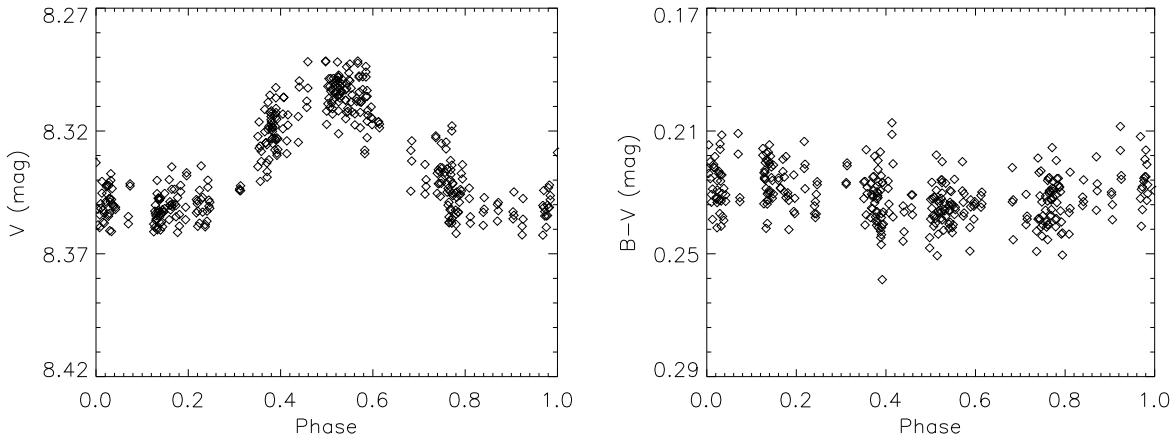

Figure 1. The first light and color curves of HD 21728.

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