Revista Mexicana de Astronomía y Astrofísica, **59**, 45–65 (2023)

https://doi.org/10.22201/ia.01851101p.2023.59.01.03

PHYSICAL PROPERTIES AND MEMBERSHIP DETERMINATION OF THE OPEN CLUSTERS IC 4665, NGC 6871 AND DZIM 5 THROUGH $uvby-\beta$ PHOTOELECTRIC PHOTOMETRY[1]

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Received December 4 2017; accepted September 13 2022

ABSTRACT

$uvby-\beta$ photoelectric photometry of stars in the direction of the open clusters IC 4665, NGC 6871 and Dzim 5 is presented. From this $uvby-\beta$ photometry we classified the spectral types which allowed us to determine the reddening and, hence, the distance. Membership of the stars to the cluster was determined. Our results are compared with those obtained by GAIA DR2.

RESUMEN

Se presenta fotometría $uvby-\beta$ de estrellas en la dirección de los cúmulos abiertos IC 4665, NGC 6871 y Dzim 5. A partir de la fotometría fotoeléctrica $uvby-\beta$ de las estrellas en la dirección de estos cúmulos clasificamos los tipos espectrales de cada estrella lo que nos permitió la determinación de su enrojecimiento y de sus distancias y, por ende, la pertenencia de las estrellas al cúmulo. Nuestros resultados se comparan con GAIA DR2.

Key Words: galaxies: photometry — open clusters and associations: general — parallaxes

1. MOTIVATION

Open clusters are a gold mine for the development of many astrophysical topics. They offer a unique opportunity, for example, to compare theoretical studies with observations; they provide opportunities to develop models of chemical enrichment with respect to the center of the galaxy, and serious studies on stability can be tested only through an analysis of open clusters. However, despite the importance of these topics, research in these fields begins with the determination of the cluster member stars.

Membership determination in open clusters is done, canonically, with proper motion studies; but in practice, main-sequence fitting is used since it is easier, although less accurate and cannot be used on a star-by-star basis. However, for distant or faint clusters membership determination is not an easy task. $uvby-\beta$ photometry of open clusters provides an accurate method for determining distances to each star and, through the global behavior, throws light on the distance to the cluster and, hence, the membership of each star to the cluster.

In this paper we present our results on three clusters: two, IC 4665 and NGC 6871, are relatively well-studied and the other, Dzim 5, has very little published information.

The open cluster IC 4665 has been a subject of many studies. The membership in the cluster has been determined in many different ways. The classical proper motions studies were done by Vasilevskis (1955) and the spectral classification of its members was done through classical spectroscopy.

With respect to the photometric studies, there are some classical works like that of Johnson (1954). With intermediate photometric bands there is the work of Crawford & Barnes (1972) who, with $uvby-\beta$ photometry, found an average cluster reddening $E(b-y)$ of 0.14, and a cluster distance modulus of 7.5, corresponding to a distance of 316 pc. They obtained the same values from an analysis of the B-type stars and the A- and F- type stars.

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Finding variables in the cluster has been a subject of some research. Barannikov (1994) confirmed that the star HD 161573 in the IC 4665 cluster has periodic ($P = 19$ d) variability.

With respect to NGC 6871 much research has been carried out. A good summary of its characteristics can be found in Southworth et al. (2004). They stated that the open cluster NGC 6871 was a concentration of bright OB stars which form the nucleus of the Cyg OB3 association. For this reason it is an important object in the study of the evolution of high-mass stars. The cluster itself has been studied photometrically several times, but the scarce data on its nature mean that determination of its physical parameters is difficult. They further note that: "UBV photometry of the 30 brightest stars was published by Hoag et al. (1961). Crawford, Barnes & Warren (1974) observed 11 stars in the Strömgren *uvby* system and 24 stars in the Crawford β system, finding significantly variable reddening and a distance modulus of 11.5 mag. This $uvby - \beta$ photometry was extended to 40 stars by Reimann (1989), who found reddening $E(b-y)$ with a mean value of 0.348 mag and an intercluster variation of about 0.1 mag. His derived distance modulus of 11.94 $\pm$ 0.08 and age of 12 Myr are both greater than previous literature values".

Southworth et al. (2004) carried out a study of the eclipsing binary V453 Cyg (W31) which, they claimed, is a member of NGC 6871. As we will see later, this is not the case.

The other cluster, Dzim 5 was reported by Dolidze & Jimsheleishvili (1966) but after this, there is only one reference to one of its members. WEBDA does not list distance, reddening age, metallicity or any other quantity except its coordinates. They refer only to the study of Kazlauskas et al., (2013) related to a new spectroscopic binary with which they establish that Dol–Dzim 5 is not a real open cluster.

Table 1 presents a summary of the most relevant findings of several papers for these clusters.

2. OBSERVATIONS

This article is a sequel to a paper on NGC 6633 that has already been published (Peña et al., 2017, Paper I). The observations were carried out over a long season by two different observers, one from June 22th to 30th and the other from July 1st to 8th, 2016 (ARL and CVR, respectively) with different objects in each one although some were taken continuously (NGC 6633, Peña et al., 2017, and V 2455 Cyg, Peña et al., 2019). The open cluster IC 4665 was observed for four nights from June 22nd to June 25th. NGC 6871 was observed for two nights, July 2nd and 3rd and Dzim 5 from July 5th to the 8th. The observing and reduction procedures were described in detail in Paper I. The reduction was done considering both seasons together as one long season to increase the accuracy of the standard stars.

The observations were all taken at the Observatorio Astronómico Nacional de San Pedro Mártir, México. The 0.84 m telescope, to which a spectrophotometer was attached, was utilized at all times. The stars to be observed were selected randomly by drawing concentric circles on the ID charts provided by WEBDA and observing all the bright stars in each circle.

The limit was the faintness of the stars, since to reach the desired accuracy faint stars would require an exceedingly long time of observation. Hence, no astrophysical considerations, nor previous knowledge of the selected stars, was considered. For IC 4665 we measured thirty stars, sixteen for NGC 6871 and fourteen for Dzim 5. Although some of the stars had already been observed, a comparison between the sets gave us confidence in the data as shown from the standard deviations of the values for the same star from several studies, in some cases from three or four different measurements. In the case of Dzim 5 averaging the large discrepancy in the color indexes m_1 and c_1 could have led to possible misinterpretations of the physical characteristics of the stars and, hence, of the cluster.

2.1. *Data Acquisition and Reduction*

During all the observed nights the following procedure was utilized: at least five ten-second integrations of each star and one ten-second integration of the sky for the *uvby* filters and the narrow and wide filters that define Hβ were done for each measurement. The reduction procedure was done with the numerical package NABAPHOT (Arellano-Ferro & Parrao, 1988). A series of standard stars was also observed on each night to transform the data into the standard system. The chosen standard system was that defined by the standard values of Olsen (1983), although some of the standard bright stars were also taken from the Astronomical Almanac (1996). The transformation equations are those defined by Crawford & Barnes (1970) and by Crawford & Mander (1966). See Paper I for details.

In these transformation equations the coefficients D, F, H and L are the slope coefficients for $(b-y)$, m_1, c_1 and β, respectively. The coefficients B, J and I are the color terms of V, m_1, and c_1. The averaged transformation coefficients of each night were listed

DOI: https://doi.org/10.22201/ia.01851101p.2023.59.01.03

TABLE 1: Compilation of the determined data of the clusters

Author	$E(B-V)$	$E(b-y)$	DM	Dst	[Fe/H]	Age	Technique
				pc		log (age)	members/total
IC 4665							
Vasilevskies (1955)							proper motion
Alcaino (1965)	0.152						UBV
Becker & Fenkart (1971)	0.17		8.11	330			UBV
Crawford & Barnes (1972)		0.14	7.5	316			$uvby-\beta$
Sanders & Van Altena (1972)						8.556	proper motion
Patenaude (1978)						7.6	theory and UBV
Nicolete (1981)			7.9 ± 0.022	379 ± 46			Geneva photometric boxes
Morrel & Abt (1991)					0.04		spectroscopy
Stetson (1991)		0.112		335	0.04	8.703	compiled
Cargile & James (2010)				357 ± 12		7.623	
PP		0.143 ± 0.046	7.5 ± 0.3	323 ± 49	-0.20 ± 0.09	8.160	$uvby-\beta$
NGC 6871							
Cohen (1969)		0.38	11.4				β
Crawford et al. (1974)			11.5				$uvby-\beta$
Schild & Ramashin (1976)			11.1				Be
Babu (1983)				1600			Spectroscopy
Nicolet (1981)			11.19 ± 0.52	1730 ± 450			Geneva
PP		0.307 ± 0.044	10.9 ± 0.04			7.088	$uvby-\beta$
DZIM 5							
Kazlauskas et al. (2013)	0.02			400	-0.09 ± 0.17		Strömvil phot and rv
PP		0.1 ± 0.1	6.62 ± 0.46	215 ± 45	-0.14 ± 0.30		$uvby-\beta$

TABLE 2

SEASONAL STANDARD DEVIATIONS OF THE STANDARD STARS

ID	σV	$\sigma(b-y)$	σm_1	σc_1	$\sigma\beta$
Mean	0.029	0.013	0.008	0.020	0.017
Stand. Dev.	0.012	0.011	0.007	0.018	0.004

in Table 2 of Paper I along with their standard deviations. Season errors, Table 2, were evaluated by means of the nineteen standard stars observed for a total of 133 observed points. These uncertainties were calculated through the differences in magnitude and colors for all nights, for (V, $b-y$, m_1, c_1 and β) as (0.024, 0.010, 0.011, 0.015, 0.015), respectively, which provide a numerical evaluation of our uncertainties of the season. Emphasis is made on the large range of the standard stars in the magnitude and the color indexes: V:(5.2, 8.8); $(b-y)$:(0.00, 0.80); m_1:(0.09, 0.68); c_1:(0.08, 1.05) and β:(2.50, 2.90).

The numerical results obtained are presented in Table 3 of Paper I. In Column 1 we present the ID; in Columns two to six, the mean photometric values V, $(b-y)$, m_1, c_1 and β for each star. The corresponding unreddened indexes are presented in the subsequent columns. The mean values of the individual standard deviations are presented at the bottom of the last two rows of Table 2 of Paper I, as well as the standard deviation of the individual standard deviations. These values are a few hundredths or thousandths of magnitude for each color index and provide the accuracy of our photometry.

Tables 3, 4 and 5 report the observed $uvby-\beta$ photoelectric photometry for IC 4665, NGC 6871 and Dzim 5, respectively. In Tables 3 and 4 we list the following: in Column 1 the ID in WEBDA, subsequent columns report the magnitude V and the color indexes $(b-y)$, m_1, c_1, and β. Since each star was observed over several nights, mean values and their standard deviations were calculated. They are also presented in the tables, as well as the number of entries in the mean. This is number N presented in the last column of each table. For the open cluster Dzim 5 we present our $uvby-\beta$ photoelectric photometry with the ID numbers shown as in Kalauskas et al. (2013).

3. COMPARISON WITH OTHER PHOTOMETRIES

A comparison with previous $uvby-\beta$ photoelectric photometry had to be done in order to test the goodness of our results and to enhance the sample by considering the previously measured stars in

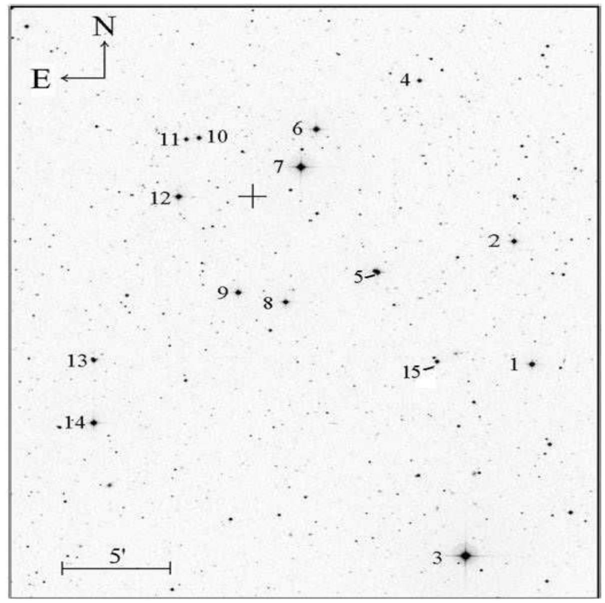

Fig. 1. ID chart of the observed stars in the direction of Dzim 5. The ID number follows that of Kalauskas et al. (2013)

the direction of each cluster. A search, mostly from WEBDA, was done for references on $uvby-\beta$ photometry. These are presented in Table 6, in which the references and the number of the reported stars are listed. However, in our comparison, we only take into account those studies with a significant number of observed stars devoted to each cluster. Those stars with few points taken randomly in studies not devoted to the cluster were not included in the mean. Later, as we will see, a compilation of the stars in the direction of each cluster was done increasing the number of stars in the direction of the cluster, with the proven quality of their values.

Instead of considering the averaged values reported by WEBDA, we opted to include the original sources, because the mean value combined with our photometry would be biased; this saved us from cases like those presented for the open cluster IC 4665. The star W108, which we did not observe, but appears in the compilation of WEBDA, had two radically different values in magnitude reported: 7.508 and 9.820. Equally discrepant are the color indexes. To check which magnitude value was correct, we compared both with those reported in UBV in WEBDA which lists 7.460 and 7.490 mag in V. These systematic differences suggest a variable star. Nevertheless, the value corresponding to 9.820 was not further considered in our analysis.

TABLE 3

OBSERVED $uvby-\beta$ PHOTOELECTRIC PHOTOMETRY OF THE OPEN CLUSTER IC 4665

ID	V	$(b-y)$	m_1	c_1	$H\beta$	σV	$\sigma(b-y)$	σm_1	σc_1	$\sigma H\beta$	N
01	6.857	0.079	0.030	0.321	2.702	0.057	0.015	0.006	0.017	0.012	3
02	7.353	0.078	0.032	0.455	2.715	0.060	0.010	0.002	0.009	0.011	3
03	7.603	0.063	0.039	0.413	2.721	0.050	0.012	0.006	0.010	0.015	3
04	7.705	0.071	0.048	0.459	2.744	0.087	0.010	0.003	0.008	0.006	2
05	9.090	0.140	0.103	0.920	2.883	0.042	0.010	0.003	0.015	0.009	3
06	10.092	0.097	0.130	0.946	2.895	0.039	0.018	0.009	0.008	0.033	3
07	9.364	0.205	0.155	0.914	2.888	0.035	0.011	0.003	0.013	0.006	3
08	10.673	0.376	0.101	0.473	2.691	0.029	0.010	0.016	0.010	0.037	3
09	10.896	0.739	0.423	0.113	2.588	0.038	0.040	0.126	0.001	0.007	3
10	9.080	0.197	0.109	0.916	2.895	0.037	0.014	0.004	0.008	0.012	3
11	7.928	0.314	0.131	0.460	2.694	0.037	0.015	0.004	0.012	0.011	3
12	10.262	0.812	0.378	0.203	2.582	0.012	0.011	0.042	0.041	0.037	3
13	8.870	0.137	0.029	0.627	2.709	0.046	0.021	0.001	0.003	0.004	2
14	8.375	0.780	0.385	0.301	2.581	0.031	0.015	0.016	0.014	0.007	3
15	9.792	0.473	0.136	0.467	2.655	0.033	0.015	0.002	0.008	0.014	3
16	10.549	0.806	0.502	0.160	2.581	0.049	0.015	0.009	0.045	0.017	3
17	8.217	0.128	0.054	0.541	2.750	0.042	0.014	0.002	0.006	0.005	3
18	10.869	0.278	0.142	0.695	2.751	0.040	0.011	0.017	0.028	0.03	3
19	8.300	1.095	0.804	0.012	2.595	0.045	0.016	0.011	0.046	0.025	3
20	9.852	0.169	0.129	0.983	2.872	0.036	0.016	0.011	0.036	0.018	3
21	10.880	0.976	0.676	-0.049	2.602	0.023	0.008	0.015	0.089	0.002	2
22	7.771	0.063	0.038	0.345	2.703	0.027	0.019	0.009	0.017	0.015	3
23	7.995	0.102	0.034	0.442	2.725	0.026	0.020	0.010	0.013	0.010	3
24	7.123	0.084	0.026	0.431	2.687	0.038	0.013	0.003	0.009	0.009	3
25	8.807	0.164	0.131	0.995	2.904	0.037	0.011	0.003	0.008	0.025	3
26	10.395	0.210	0.159	0.864	2.843	0.025	0.018	0.008	0.019	0.026	3
27	10.942	0.433	0.070	0.409	2.609	0.030	0.020	0.012	0.039	0.033	3
28	7.480	0.077	0.159	0.979	2.899	0.029	0.009	0.003	0.001	0.003	2
29	9.745	0.373	0.123	0.277	2.597	0.033	0.007	0.004	0.011	0.008	2
30	10.188	0.800	0.550	0.254	2.595	0.032	0.016	0.042	0.094	0.021	3

All the analysis of the data of the three clusters is calculated in a linear fit in which the oldest source data are considered on the X axis and the newest, on the Y axis. A linear relation was calculated in a formula $Y_{new} = A + BX_{old}$. The goodness of the fit is demonstrated by both the correlation coefficient R and the standard deviation of the points. For a good fit, A should be small and B close to 1. The correlation coefficient, R, has to be near unity and the standard deviation, small. All the values obtained for each cluster are presented in Table 7. The final column in the table presents N, the number of entries. Figures 2, 3 and 4 present the comparisons among the principal data sets for IC 4665 (Crawford and Barnes (1972) vs present paper; for NGC 6871 Crawford et al. (1974) vs. Reimann (1989) and Kazlauskas (2013) vs. present paper, respectively.

For the cluster IC 4665 we considered the original sources of Crawford & Barnes (1972) with forty-five entries; of Stetson (1991) with only six measured stars; and our photometry (58 stars), to calculate the mean values of the stars. Of all the sets only star W32 showed anomalies. Its reported V magnitude in Crawford & Barnes (1972) is 10.188, whereas the V magnitude in Stetson (1991), is 8.330. The large difference could be due to either intrinsic variability or eclipses. We ended up with a sample of fifty-six stars of which ten are presented for the first time, four measured in the three sets and thirteen in the intersection of Crawford & Barnes (1972) and the

TABLE 4

OBSERVED $uvby-\beta$ PHOTOELECTRIC PHOTOMETRY OF THE OPEN CLUSTER NGC 6871

ID	V	$(b-y)$	m_1	c_1	$H\beta$	σV	$\sigma(b-y)$	σm_1	σc_1	$\sigma H\beta$	N
01	6.782	0.088	0.167	-0.240	2.473	0.017	0.010	0.000	0.015	0.001	2
03	7.339	0.252	-0.053	-0.055	2.541	0.016	0.003	0.008	0.016	0.006	2
05	7.889	0.262	-0.047	-0.076	2.553	0.035	0.003	0.001	0.007	0.005	2
08	8.700	0.225	-0.050	0.049	2.611	0.076	0.008	0.003	0.040	0.005	2
25	11.662	0.276	-0.039	0.275	2.718	0.029	0.010	0.013	0.020	0.018	2
24	11.721	0.233	0.026	0.279	2.699	0.029	0.011	0.007	0.039	0.018	2
153	8.474	0.884	0.532	0.332	2.558	0.006	0.004	0.020	0.006	0.006	2
07	8.779	0.225	-0.056	0.006	2.596	0.025	0.016	0.021	0.016	0.006	2
04	7.746	0.200	-0.022	-0.148	2.564	0.006	0.000	0.001	0.004		2
09	9.473	0.384	0.175	0.275	2.575	0.003	0.001	0.009	0.008	0.012	2
02	7.270	0.252	-0.055	-0.038	2.547	0.003	0.001	0.001	0.005	0.008	2
13	10.368	0.217	-0.024	0.126	2.690	0.021	0.000	0.013	0.011	0.011	2
31	8.423	0.222	-0.037	-0.021	2.575	0.234	0.001	0.004	0.008	0.008	2
12	10.347	0.343	0.157	0.321	2.628	0.007	0.008	0.012	0.012	0.018	2
15	10.791	0.246	-0.006	0.075	2.639	0.006	0.009	0.006	0.002	0.066	2
10	10.404	0.259	0.145	0.797	2.727	0.408	0.011	0.012	0.017	0.003	2

TABLE 5

OBSERVED $uvby-\beta$ PHOTOELECTRIC PHOTOMETRY OF THE OPEN CLUSTER DZIM 5

ID	V	$(b-y)$	m_1	c_1	Hβ	σV	σ $(b-y)$	σm_1	σc_1	σ Hβ	N
K07	9.254	0.815	0.780	0.194	2.570	0.003	0.000	0.008	0.021	0.013	3
K06	10.179	0.393	0.247	0.292	2.619	0.009	0.008	0.016	0.011	0.037	3
K10	11.444	0.331	0.130	0.324	2.605	0.014	0.010	0.014	0.014	0.031	3
K11	11.920	0.385	0.181	0.327	2.598	0.009	0.020	0.031	0.009	0.037	3
K12	10.357	0.538	0.375	0.323	2.560	0.006	0.001	0.009	0.012	0.007	3
K13	11.293	0.405	0.228	0.285	2.597	0.082	0.016	0.024	0.021	0.017	3
K14	10.001	0.315	0.145	0.397	2.655	0.043	0.003	0.008	0.010	0.028	3
K09	10.556	0.316	0.154	0.385	2.658	0.052	0.017	0.017	0.008	0.016	3
K08	10.608	0.646	0.523	0.323	2.562	0.012	0.008	0.011	0.011	0.029	3
K05	10.752	0.486	0.192	0.382	2.632	0.078	0.012	0.006	0.013	0.014	2
K15	11.828	0.406	0.237	0.382	2.674	0.104	0.030	0.040	0.045	0.044	3
K01	10.378	0.305	0.169	0.424	2.668	0.009	0.006	0.014	0.013	0.003	3
K02	11.178	0.820	0.726	0.245	2.571	0.017	0.020	0.048	0.059	0.036	3
K04	11.943	0.298	0.167	0.305	2.653	0.027	0.027	0.038	0.029	0.048	3

present paper's photometry. Only two were measured in both data sets of the literature, Crawford & Barnes (1972) and Stetson (1991). The mean value for each star is presented in Table 8 along with the standard deviation of each color index.

The column of photometric sources lists the authors whose values we consider in the mean; these are listed at the bottom of the table. The last column presents the spectral type determined from the $uvby-\beta$ photoelectric photometry in a procedure described below.

These coefficients are adequate despite the fact that the span of the color index limits is rather low, particularly in $(b-y)$ from 0 to 0.4; m_1 from 0 to 0.2. On the other hand, the magnitude V limits go from 7 to 11 mag. The linear fit in β was done without W88 which showed a relatively large difference (0.064).

The final list of compiled $uvby-\beta$ photoelectric photometry of IC 4665 is presented in Table 8. Col-

TABLE 6

REFERENCES WITH $uvby - \beta$ PHOTOMETRY FOR THE THREE CLUSTERS

Source	Number of reported stars
IC 4665	
Crawford & Barnes (1972)	47
Perry & Johnston (1982)	2
Schmidt (1982)	1
Olsen (1983)	2
Schuster & Nissen (1988)	2
Sinachopoulos (1990)	2
Stetson (1991)	6
Olsen (1993)	1
Present Paper (2022)	29
Total Number	57
NGC 6871	
Cohen (1969)	8
Crawford et al. (1974)	8
Crawford (1975)	1
Reimann (1989)	18
Present Paper (2022)	16
Total Number	23
DZIM 5	
Kazlauskas, (2013)	14
Present Paper (2022)	14
Total Number	15

umn 1 lists the ID of WEBDA, subsequent columns present the mean magnitudes V and color indexes $(b-y)$, m_1, c_1, and β. The standard deviations are also presented, as well as the references utilized in the mean. The references are presented at the bottom of the table.

For NGC 6871 Crawford et al. (1974) observed 8 stars in the complete $uvby - \beta$ system and 12 only in β; Reimann (1989) presented the majority of the observed stars, a sample of 18 stars in the $uvby - \beta$ system and 22 stars in $uvby$ only. His star 101 is considered to be W31. One more source, Cohen (1969) observed eight stars of the cluster but only in β. The same procedure as in IC 4665 was done, and the coefficients of the cross fits are presented in Table 7. The mean values of the three sources are listed in Table 9, along with the standard deviation and the number of sources involved in the mean. The whole sample is constituted of 23 stars.

In this table all but three stars have standard deviations on the order of hundredths of magnitude. These three stars are W08, W10 and W25. W08 and W25 which were observed by us and are listed in

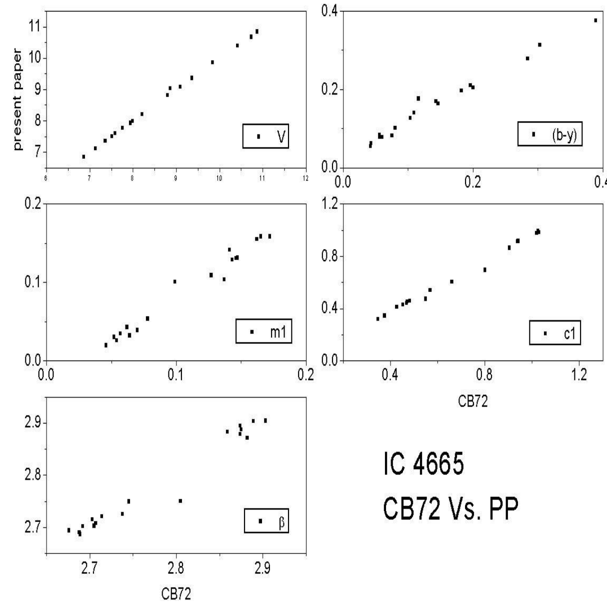

Fig. 2. Comparison of Crawford and Barnes (1972) vs. present paper's photometry for IC 4665.

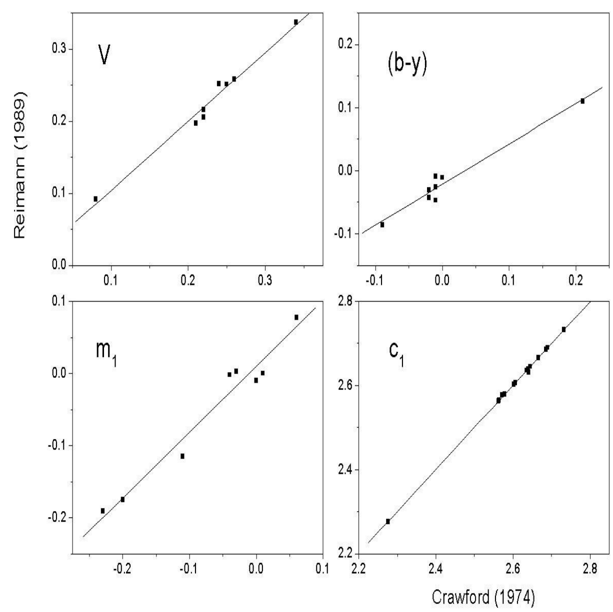

Fig. 3. Comparison of Crawford et al. (1974) vs. Reimann's photometry for NGC 6871.

the table, presented dispersions on the order of hundredths of magnitude, so the high dispersion found in Table 9 is due to either the photometry among the different sources Crawford et al. (1974), Reimann (1989) and Cohen (1969) and ours for star W08 or Crawford et al. (1974), Reimann (1989) and ours for star W25. For W10 we found a dispersion of 0.408,

TABLE 7

LINEAR REGRESSION OF THE $uvby-\beta$ COLOR INDEXES: PRESENT PAPER'S DATA VS. THE LITERATURE

	IC 4665				
Index	A	B	R	Std Dev	N
Crawford & Barnes (1972)	vs.	Stetson (1991)			
V	-0.1437	1.0020	0.9999	0.0411	6
$(b-y)$	-0.0011	0.9647	0.9995	0.0029	6
m_1	-0.0076	1.0369	0.9974	0.0036	6
c_1	-0.0170	1.0396	0.9996	0.0088	6
β	-0.4740	1.1725	0.9999	0.0011	6
Crawford & Barnes (1972)	vs.	Present Paper			
V	0.0460	0.9950	0.9990	0.0454	18
$(b-y)$	0.0308	0.9075	0.9903	0.0131	18
m_1	-0.0322	1.1326	0.9863	0.0090	18
c_1	-0.0230	0.9812	0.9959	0.0234	18
β	-0.0217	1.0089	0.9812	0.0179	17
	NGC 6871				
Crawford et al. (1974)	vs.	Reimann (1989)			
$(b-y)$	0.0087	0.9554	0.9908	0.0102	8
m_1	-0.0219	0.6423	0.9784	0.0128	8
c_1	0.0101	0.9139	0.9796	0.0209	8
β	0.0087	0.9966	0.9996	0.0030	15
Reimann (1989)	vs.	Present Paper			
V	-0.0305	1.0017	0.9979	0.1143	14
$(b-y)$	0.0131	0.9664	0.9797	0.0141	14
m_1	-0.0086	1.3661	0.9578	0.0279	14
c_1	-0.0247	1.3017	0.9872	0.0433	14
β	-1.0105	1.3866	0.9797	0.0143	10
Cohen (1969)	vs.	Present Paper			
β	-1.2661	1.4849	0.9746	0.0071	6
	DZIM 5				
Kazkalauskas et al (2013)	vs.	Present Paper			
V	-0.0921	1.0068	0.9998	0.0181	12
$(b-y)$	0.0078	0.9695	0.9987	0.0103	12
m_1	0.0959	0.5963	0.1167	0.2419	12
c_1	0.3938	-0.2354	-0.7397	0.0451	12

the highest of all the sample. This value was compared with that of Reimann (1989). There is always the possibility that this might show a variable nature of the star.

For the open cluster Dzim 5 there are only two sources with Strömgren photometry, that of Kazlauskas et al., (2013) with only 13 measured stars and ours, with 14 stars. In both sets, basically the same stars were measured. Only two, one in each set, were observed separately. Star 5 was identified but no $uvby-\beta$ measurements are presented. The whole sample therefore contains fifteen stars. Studying the results of the coefficients derived from the linear regression of the $uvby-\beta$ color indexes (newest data vs. older data in the literature) for the three clusters, we observe that R, the correlation coefficient, is always larger than 0.9, and that the standard deviation is less than few hundredths of magnitude implying that all data sets are consistent, except for those in DZIM 5. In DZIM 5 the correlation coefficient

TABLE 8

COMPILED $uvby-\beta$ PHOTOELECTRIC PHOTOMETRY OF IC 4665

ID	V	$(b-y)$	m_1	c_1	Hβ	σV	$\sigma\ (b-y)$	σm_1	σc_1	σ Hβ	Photom. Source	SpTyp
7	9.310	0.315	0.163	0.744	2.774						1	A9Vp
22	8.780	0.089	0.077	0.798	2.771							A0V1
23	8.060	0.070	0.093	0.825	2.826						1	A0V
27	10.320	0.172	0.160	0.978	2.899						1	A4V
28	7.432	0.240	0.105	0.978	2.775	0.003	0.005	0.000	0.008	0.004	1,2	A2V
32	8.330	0.067	0.066	0.964	2.733						1	A8I
34	11.000	0.457	0.091	0.474	2.712						1	F2V
37	11.360	0.384	0.114	0.574	2.698						1	F0V
38	10.702	0.382	0.100	0.512	2.690	0.040	0.009	0.001	0.054	0.002	1,3	F0V
39	9.377	0.199	0.159	0.943	2.887	0.026	0.006	0.004	0.030	0.011	1,2,3	A3V
42	10.896	0.739	0.423	0.056	2.588						3	LATE
43	9.090	0.125	0.120	0.931	2.871	0.000	0.022	0.024	0.015	0.017	1	A2V
44	10.092	0.097	0.130	0.946	2.895						3	A2V
47	9.764	0.380	0.118	0.287	2.623						3	F7V
48	11.580	0.392	0.088	0.510	2.669						1	F0V
49	7.691	0.057	0.072	0.471	2.735	0.006	0.001	0.007	0.001	0.002	1,3	A V
50	9.085	0.190	0.118	0.927	2.885	0.007	0.011	0.013	0.015	0.015	1,3	A2V
51	9.850	0.270	0.100	0.962	2.889						1	A2V
53	11.410	0.366	0.113	0.527	2.702						1	F0V
56	7.504	0.079	0.162	0.999	2.904	0.008	0.005	0.004	0.030	0.001	1,3	A2V
57	11.130	0.327	0.137	0.602	2.698						1	
58	7.599	0.049	0.058	0.424	2.714	0.008	0.012	0.016	0.010	0.007	1,2,3	B V
59	11.030	0.907	0.466	0.485	2.582						1	LATE
62	6.857	0.065	0.043	0.337	2.692	0.003	0.012	0.011	0.014	0.010	1,2,3	B V
63	10.560	0.222	0.167	0.837	2.834						1	A4V
64	7.357	0.067	0.048	0.462	2.709	0.005	0.016	0.022	0.011	0.009	1,3	B V
65	10.600	0.278	0.165	0.716	2.760						1	A8Vp
66	10.403	0.203	0.165	0.884	2.877	0.011	0.010	0.009	0.029	0.004	1,3	A5V
67	8.803	0.155	0.139	1.010	2.897	0.005	0.013	0.011	0.021	0.011	1,3	A3V
68	7.936	0.309	0.139	0.471	2.685	0.010	0.008	0.011	0.015	0.013	1,3	F0V
70	10.262	0.812	0.378	0.203	2.582						3	LATE
71	10.942	0.433	0.070	0.409	2.656						3	
72	7.765	0.048	0.053	0.360	2.704	0.008	0.009	0.013	0.021	0.001	1,3	B V
73	7.126	0.070	0.040	0.442	2.688	0.005	0.020	0.020	0.015	0.001	1,3	B V
74	10.549	0.806	0.502	0.160	2.581						3	LATE
76	8.213	0.115	0.066	0.554	2.747	0.005	0.017	0.017	0.019	0.003	1,3	B V
81	8.924	0.136	0.036	0.644	2.705	0.092	0.035	0.014	0.033	0.004	1,2,3	A0V
82	7.993	0.091	0.046	0.455	2.732	0.004	0.015	0.016	0.018	0.009	1,3	B V
83	10.210	0.191	0.137	0.996	2.888						1	A3V
84	9.792	0.473	0.136	0.467	2.655						3	G0V
86	10.390	0.412	0.102	0.574	2.663						1	F0V
88	10.858	0.281	0.141	0.747	2.778	0.017	0.004	0.000	0.074	0.038	1,3	A6V
89	9.846	0.156	0.136	1.006	2.877	0.009	0.018	0.010	0.032	0.007	1,3	A0V
90	8.300	1.095	0.804	0.012	2.595						3	LATE
92	10.845	0.974	0.676	0.281	2.562						3	LATE
95	9.880	1.256	0.470	0.591	0.000						1	LATE
96	8.907	0.490	0.335	0.284	2.555						1	LATE
98	8.375	0.780	0.385	0.301	2.581						3	LATE
99	7.530	1.259	0.232	0.904	0.000						1	LATE
102	9.290	0.111	0.136	1.092	2.908						1	A2V
105	7.490	0.040	0.084	0.535	2.732						1	B V
111	10.000	0.282	0.168	0.727	2.765						1	A9Vp
115	9.150	0.275	0.182	0.705	2.788						1	A8Vp
118	10.320	0.235	0.120	0.986	2.910						1	A3V
121	8.610	0.245	0.166	1.056	2.838						1	A4V
125	9.700	0.142	0.130	1.156	2.882						1	F2Ib
178	7.705	0.071	0.048	0.459	2.744						3	B V

Note: 1 Crawford, 1971; 2 Stetson, 1991; 3 PP.

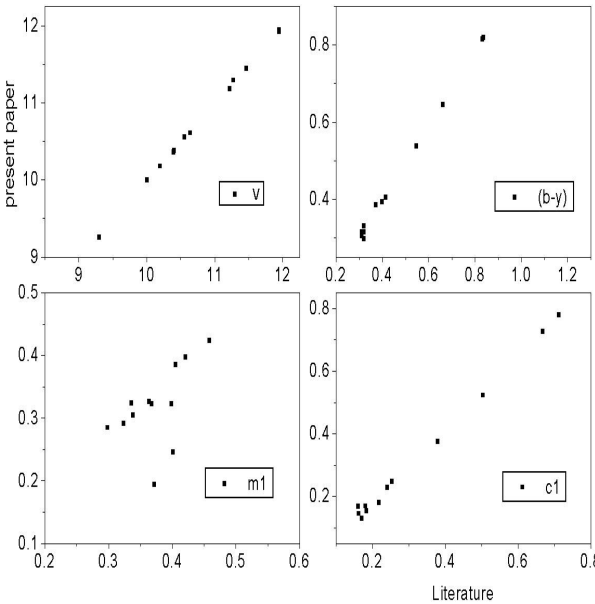

Fig. 4. Comparison of Kazlauskas (2013) vs. present paper photometry for Dzim 5.

R gave anomalous values in m_1 and c_1 implying, of course, no correlation between both sets. In view of this, we averaged only V and $(b-y)$ in the sets of Dzim 5 between Kazlauskas et al. (2013) vs. present paper. Their photometry did not include Hβ. The averaged values are presented in Table 10, following Kazlauskas et al., (2013) ID numbers: In Figure 1, star 15 was added because it was not observed by Kazlauskas et al., (2013). Because of the poor linear regression in m_1 and c_1 the average was done only for V and $(b-y)$. Table 10 presents the mean of the $uvby-\beta$ photometry and the standard deviation of the sources.

4. DETERMINATION OF CLUSTER PARAMETERS

In order to determine the physical characteristics of the stars in the three clusters, IC 4665, NGC 6871 and Dzim 5, the same procedure as in Paper I for NGC 6633 was carried out. This procedure briefly, consists of the following steps:

To evaluate the reddening we first established to which spectral class the stars belong: early (B and early A) or late (late A and F stars) types; the later class stars (G or later) were not considered in the analysis since there is no reddening calibration for MS stars.

To determine the spectral type of each star we utilized the compiled $uvby-\beta$ photoelectric photometry of each open cluster calculating the unreddened indexes $[m1]$, $[c1]$ and compared their position with the stars of the open cluster Alpha Per (Peña & Sareyan, 2006) for which the stars have well-defined spectral class. The results are presented schematically in Figures 5, 6 and 7 for IC 4665, NGC 6871 and Dzim 5, respectively. The last column of each compiled $uvby-\beta$ photoelectric photometry presents the assigned spectral type.

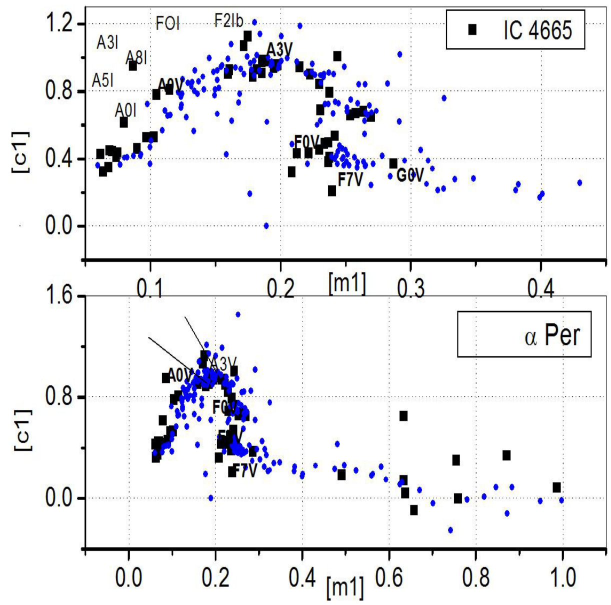

Fig. 5. Position of the stars of IC 4665 in the $[m_1]-[c_1]$ (filled squares) diagram of α Per (Peña & Sareyan, 2006), dots. The color figure can be viewed online.

The photoelectrically classified spectral types of the stars are in very good agreement with those obtained by spectroscopy and reported by WEBDA. It can be seen that the observed stars, which are the brightest in the field, are of all spectral types in the case of NGC 6871 but all late type stars for Dzim 5.

The reddening was determined through Strömgren photometry once the spectral types were classified. The application of the calibrations for each spectral type, of Balona & Shobbrook (1984) and Shobbrook (1984) for O and early A type and of Nissen (1988) for late A and F stars, respectively, allowed us to determine their reddening and hence, their unreddened color indexes. As has been said, no determination of reddening was calculated for G or later spectral types. The procedure has been extensively described in Peña & Martínez (2014). Once the reddening is calculated, the distances can be determined for each star.

The output for the three clusters is presented in Tables 11, 12, and 13 for IC 4665, NGC 6871 and

TABLE 9

COMPILED $uvby-\beta$ PHOTOELECTRIC PHOTOMETRY OF NGC 6871

ID	V	$(b-y)$	m_1	c_1	Hβ	σV	$\sigma\ (b-y)$	σm_1	σc_1	σ Hβ	Photom. Source	SpTyp
1	6.788	0.087	0.162	-0.220	2.473	0.008	0.006	0.050	0.026		1,2,3,4	
2	7.288	0.251	-0.035	-0.016	2.558	0.025	0.001	0.018	0.019	0.010	1,2,3,4	B V
3	7.353	0.248	-0.037	-0.027	2.556	0.021	0.007	0.023	0.029	0.011	1,2,3,4	B V
4	7.767	0.202	-0.011	-0.124	2.571	0.029	0.007	0.011	0.020	0.006	1,2,3,4	B V
5	7.902	0.260	-0.037	-0.039	2.570	0.018	0.002	0.014	0.037	0.013	1,2,4	B V
6	8.187	0.339	-0.088	-0.188	2.276		0.002	0.003	0.018	0.175	1,2,4	B V
7	8.792	0.217	-0.025	0.005	2.600	0.019	0.010	0.027	0.005	0.162	1,2,3,4	B V
8	8.790	0.220	-0.029	0.062	2.608	0.127	0.004	0.020	0.014	0.003	1,2,3,4	B V
9	9.452	0.383	0.159	0.256	2.575	0.030	0.001	0.022	0.028		2,3	F9V
10	10.263	0.262	0.122	0.822	2.727	0.199	0.005	0.032	0.035		2,3	A2V
11	10.332	0.205	-0.005	0.075	2.636						2	B V
12	10.335	0.345	0.133	0.314	2.628	0.017	0.003	0.034	0.009		1,2	F9V
13	10.372	0.210	-0.002	0.116	2.660	0.006	0.011	0.031	0.014	0.026	1,2	B V
14	10.796	0.210	-0.004	0.244	2.637					0.006	1,2	B V
15	10.776	0.254	-0.020	0.118	2.639	0.021	0.012	0.020	0.061	0.000	1,2,3	B V
16	10.980	0.203	0.009	0.255	2.550					0.141	1,2	B V
17	11.251	0.320	-0.019	0.238							2	B V
18	11.319	0.171	0.094	1.225							2	F2Ib
19	11.542	0.194	0.024	0.298							2	B V
20	11.558	0.256	0.015	0.612	2.571						2	B V
21	11.661	0.244	-0.040	0.380	2.666					0.000	1,2	B V
22	11.646	0.214	0.110	0.896							2	A2V
23	11.638	0.172	0.084	0.177							2	
24	11.732	0.229	0.032	0.253	2.690	0.017	0.005	0.008	0.036	0.008	1,2,3	B V
25	11.761	0.256	-0.017	0.293	2.699	0.140	0.029	0.031	0.025	0.016	1,2,3	B V
26	11.830	0.230	0.102	0.832							2	A2V
27	11.874	0.286	-0.016	0.335	2.732					0.000	1,2	B V
28					2.77						1	
29					2.782						1	
30					2.788						1	
31=R101	8.402	0.218	-0.025	-0.010	2.583	0.029	0.006	0.018	0.014	0.011	2,3	B V
R102	9.780	1.094	0.431	0.274							2	LATE
R103	12.117	0.220	0.024	0.481							2	B V
R104	11.259	0.260	0.012	0.479							2	B V
R105	11.756	0.388	0.056	0.431							2	A0V
R106	11.718	0.261	-0.002	0.227							2	
R107	10.775	0.239	0.077	0.857							2	B V

Note: 1 Crawford, 1974; 2 Reimann, 1989; 3 PP, 4 Cohen.

Dzim 5, respectively. In each table Column 1 lists the ID of the star, Column 2 the reddening $E(b-y)$; Columns 3 to 5 the unreddened indexes $(b-y)$, m_1, c_1; Column six lists $H\beta$, the remaining columns list the V_0 and the absolute magnitude M_V. The next two columns present the distance modulus, in magnitudes, and the distance in parsecs. In the case of F type stars we present [Fe/H]. The last column provides the assigned membership, either M for the member stars or N for the non-members. Member stars within one sigma from the mean are considered members, the others, non-members. Figures 8, 10 and 11 present the histograms of the distance modulus for the stars.

TABLE 10

COMPILED $uvby-\beta$ PHOTOELECTRIC PHOTOMETRY OF DZIM 5

ID	V	$(b-y)$	m_1	c_1	$H\beta$	σV	$\sigma(b-y)$	Photom. Source	
1	10.390	0.308	0.169	0.424	2.668	0.018	0.004	1,2	F9V
2	11.198	0.828	0.726	0.245	2.571	0.027	0.012	1,2	LATE
3	08.763	1.115	0.719	0.528				1	
4	11.944	0.309	0.167	0.305	2.653	0.000	0.016	1,2	G0
5	10.752	0.486	0.192	0.382	2.632			2	LATE
6	10.188	0.397	0.247	0.292	2.619	0.013	0.005	1,2	LATE
7	09.275	0.823	0.780	0.194	2.570	0.031	0.011	1,2	LATE
8	10.622	0.654	0.523	0.323	2.562	0.021	0.012	1,2	LATE
9	10.557	0.313	0.154	0.385	2.658	0.001	0.003	1,2	F9V
10	11.456	0.326	0.130	0.324	2.605	0.016	0.008	1,2	F8
11	11.932	0.378	0.181	0.327	2.598	0.018	0.010	1,2	G1V
12	10.374	0.542	0.375	0.323	2.560	0.024	0.006	1,2	LATE
13	11.284	0.410	0.228	0.285	2.597	0.012	0.007	1,2	LATE
14	10.002	0.317	0.145	0.397	2.655	0.001	0.003	1,2	F8V
15	11.828	0.406	0.237	0.382	2.674			2	LATE

Note: 1 Kazlauskas (2013, V and $(b-y)$ only; 2 PP.

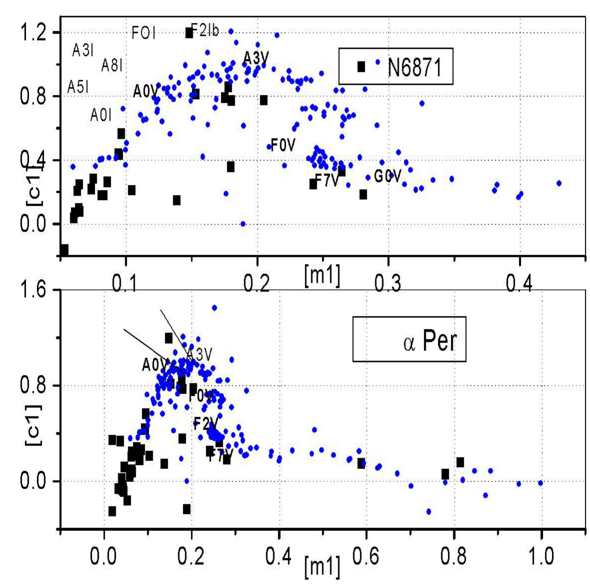

Fig. 6. Position of the stars of NGC 6871 in the $[m_1]-[c_1]$ (filled squares) diagram of α Per (Peña & Sareyan, 2006), dots. The color figure can be viewed online.

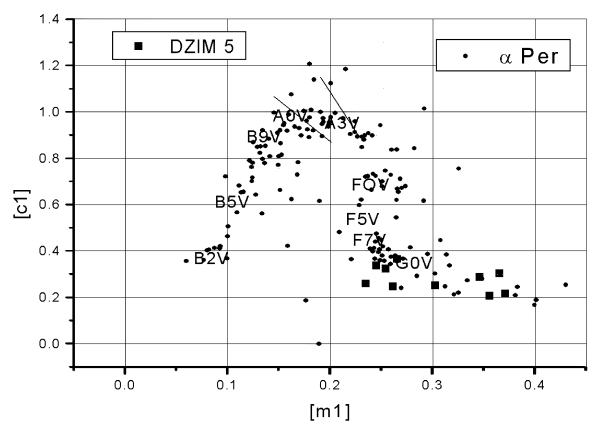

Fig. 7. Position of the stars of Dzim 5 in the $[m_1]-[c_1]$ (filled squares) diagram of Alpha Per (Peña & Sareyan, 2006).

As can be seen in Figure 8, in the case of IC 4665, the Gaussian peak is at 7.5 ± 0.6. Those stars within these limits are considered to be member stars and are denoted by M in Table 11. Those outside these limits are considered to be non-members and are denoted by NM in the same table. The last column of Table 11 lists the membership probabilities reported by WEBDA. For IC 4665 out of forty-four compiled stars within the spectral class limits, twenty five can be considered members of the cluster. Of these, eleven stars have high membership probability reported by WEBDA, larger than 0.7 and only four have very low membership probability. Of the nineteen stars that we considered out of the cluster limits, only three have been assigned a high membership probability in the literature. So, overall, the agreement is not bad and, hence, the membership that we assigned for those eight stars that did not have previously assigned probability is a new and important result. Among the F type stars that are within the distance limits there are five stars with determined [Fe/H]. The mean value gives -0.221 ± 0.230 if the large value of -0.597 of W71 is considered; without

TABLE 11

REDDENING AND UNRREDDENED PARAMETERS OF IC 4665

ID	$E(b-y)$	$(b-y)_0$	m_0	c_0	Hβ	V_0	M_V	DM	Distance	[Fe/H]	Membership	Probab
											PP	Webda
49	0.000	0.228	0.072	0.471	2.735	7.69	4.54	3.15	43		NM	0.85
68	0.052	0.257	0.155	0.461	2.685	7.71	3.53	4.19	69	-0.09	NM	
47	0.053	0.327	0.134	0.276	2.623	9.53	4.99	4.54	81	-0.50	NM	
115	0.112	0.163	0.216	0.683	2.788	8.67	3.26	5.41	121		NM	
56	0.096	-0.017	0.191	0.981	2.904	7.09	1.31	5.78	143		NM	
34	0.227	0.230	0.159	0.429	2.712	10.02	4.06	5.97	156	-0.11	M	
07	0.145	0.170	0.206	0.715	2.774	8.69	2.69	5.99	158		M	
84	0.171	0.302	0.187	0.433	2.655	9.06	3.02	6.04	161	0.26	M	0
28	0.266	-0.026	0.185	0.927	2.775	6.29	-0.19	6.48	197		M	
71	0.153	0.280	0.116	0.378	2.656	10.28	3.75	6.54	203	-0.60	M	
67	0.173	-0.018	0.191	0.977	2.897	8.06	1.25	6.81	231		M	0.74
111	0.103	0.179	0.199	0.706	2.765	9.56	2.71	6.85	234		M	
38	0.135	0.247	0.141	0.485	2.690	10.12	3.20	6.92	242	-0.30	M	0.04
50	0.221	-0.031	0.184	0.885	2.885	8.13	1.17	6.96	247		M	0.84
23	0.107	-0.037	0.125	0.805	2.826	7.60	0.61	6.99	250		M	
66	0.130	0.073	0.204	0.858	2.877	9.84	2.69	7.15	270		M	0.86
121	0.158	0.087	0.213	1.024	2.838	7.93	0.77	7.17	271		M	
39	0.229	-0.03	0.228	0.900	2.887	8.39	1.18	7.21	277		M	0.86
51	0.299	-0.029	0.190	0.905	2.889	8.56	1.20	7.36	297		M	
62	0.147	-0.082	0.087	0.309	2.692	6.23	-1.15	7.38	299		M	0.02
43	0.154	-0.029	0.166	0.902	2.871	8.43	1.03	7.39	301		M	0.83
63	0.110	0.112	0.200	0.815	2.834	10.09	2.69	7.39	301		M	
178	0.137	-0.066	0.089	0.433	2.744	7.11	-0.34	7.45	309		M	0
65	0.094	0.184	0.193	0.697	2.760	10.20	2.74	7.46	311		M	0.87
53	0.130	0.236	0.152	0.501	2.702	10.85	3.36	7.49	314	-0.17	M	0.23
102	0.101	0.010	0.166	1.073	2.908	8.86	1.30	7.56	325		M	0
105	0.097	-0.057	0.113	0.516	2.732	7.07	-0.49	7.56	325		M	0
64	0.133	-0.066	0.088	0.437	2.709	6.79	-0.84	7.62	335		M	0.83
88	0.114	0.167	0.175	0.724	2.778	10.37	2.73	7.64	337		M	0.84
73	0.138	-0.068	0.082	0.416	2.688	6.53	-1.20	7.73	352		M	0.47
76	0.172	-0.057	0.118	0.521	2.747	7.47	-0.28	7.75	355		M	0.78
82	0.158	-0.067	0.093	0.425	2.732	7.31	-0.50	7.81	365		M	0.8
118	0.260	-0.025	0.198	0.937	2.910	9.20	1.38	7.83	368		M	
58	0.119	-0.070	0.094	0.401	2.714	7.09	-0.76	7.85	372		M	0.88
86	0.139	0.273	0.144	0.546	2.663	9.79	1.90	7.89	379	-0.25	M	
37	0.145	0.239	0.158	0.545	2.698	10.73	2.79	7.94	388	-0.08	M	0.1
89	0.175	-0.019	0.188	0.973	2.877	9.09	1.06	8.04	405		M	0.22
83	0.213	-0.022	0.201	0.956	2.888	9.29	1.17	8.12	421		M	0.8
72	0.126	-0.078	0.091	0.336	2.704	7.22	-0.95	8.17	430		M	0.46
27	0.196	-0.024	0.219	0.941	2.899	9.48	1.28	8.20	436		M	
57	0.089	0.238	0.164	0.584	2.698	10.75	2.51	8.24	444	0.00	M	0.67
48	0.127	0.265	0.126	0.485	2.669	11.03	2.78	8.26	448	-0.45	M	
32	0.000	0.18	0.066	0.964	2.733	8.33	0.06	8.27	451		M	0.58
22	0.128	-0.039	0.115	0.774	2.771	8.23	-0.07	8.30	457		M	
44	0.124	-0.027	0.167	0.922	2.895	9.56	1.25	8.31	459		NM	
81	0.185	-0.049	0.092	0.609	2.705	8.13	-1.03	9.15	677		NM	0.86
Mean	0.152							7.43	319	-0.19		
Std dev	0.056							0.64	85	0.25		

this value the mean value of [Fe/H] is -0.127 ± 0.107. At any rate, for our analysis we considered a solar value. WEBDA does not assign a metallicity value for IC 4665. Figure 9 presents the distance modulus histograms for each spectral type. In Figure 9 it can be seen the peaks for each spectral group, F, A, B and combined; they are all centered at the same distance modulus.

For NGC 6871 most of the observed stars could not be analyzed with the prescriptions to determine the reddening because many of them did not have Hβ measurements. With the compiled sample of

TABLE 12

REDDENING AND UNREDDENED PARAMETERS OF NGC 6871

ID	$E(b-y)$	$(b-y)_0$	m_0	c_0	$H\beta$	V_0	M_V	DM	Distance (pc)	Membership (pp)
12	0.012	0.328	0.134	0.308	2.620	10.3	4.6	5.6	134	NM
25	0.022	0.228	-0.003	0.286	2.690	11.7	5.5	6.1	168	NM
37	0.484	-0.034	0.135	0.848	2.950	10.4	1.7	8.7	541	NM
10	0.057	0.203	0.137	0.809	2.720	10.0	1.1	9.0	621	NM
8	0.335	-0.115	0.080	-0.004	2.600	7.4	-3.6	11.0	1574	close
27	0.368	-0.088	0.100	0.260	2.730	10.3	-0.7	11.0	1581	close
13	0.320	-0.110	0.096	0.049	2.660	9.0	-2.2	11.2	1734	close
7	0.329	-0.119	0.079	-0.063	2.600	7.4	-3.9	11.3	1806	close
5	0.383	-0.123	0.085	-0.103	2.570	6.3	-5.1	11.4	1886	close
31	0.338	-0.120	0.076	-0.074	2.583	6.95	-4.47	11.42	1924	close
24	0.316	-0.096	0.125	0.190	2.690	10.4	-1.4	11.7	2208	far
11	0.314	-0.114	0.094	0.010	2.630	9.0	-2.9	11.9	2354	far
14	0.307	-0.097	0.092	0.182	2.630	9.5	-2.5	12.0	2459	far
15	0.361	-0.111	0.088	0.041	2.630	9.2	-2.8	12.0	2483	far
21	0.320	-0.080	0.056	0.319	2.660	10.3	-1.8	12.0	2549	far
4	0.330	-0.130	0.089	-0.183	2.570	6.3	-5.8	12.2	2711	far
Mean (close)								11.2	1751	close
Std dev								0.2	149	
Mean (far)								12.0	2461	far
Std dev								0.2	171	

TABLE 13

REDDENING AND UNREDDENED PARAMETERS OF DZIM 5

ID	$E(b-y)$	$(b-y)_0$	m_0	c_0	Hβ	V_0	M_V	DM	Distance	[Fe/H]
12	0.020	0.285	0.175	0.420	2.668	10.29	3.76	6.53	203	0.164
8	0.022	0.294	0.161	0.381	2.658	10.46	4.07	6.39	190	-0.051
7	0.021	0.294	0.151	0.393	2.655	9.91	3.88	6.03	161	-0.174
14	0.000	0.306	0.167	0.305	2.653	11.94	4.98	6.96	247	0.004
3	0.000	0.340	0.130	0.324	2.605	11.44	4.26	7.19	274	-0.627
Mean	0.01							6.62	215	-0.14
Std dev	0.01							0.46	45	0.30

Table 9, represented schematically in Figure 3, we realized that most of the stars lie in the early type stars branch. The applicable prescription for early type stars gives the results presented in Table 12. In this table we have separated the stars in three categories depending on their distance; the first group labelled as non-members, and for the second and third group, those below and above distance modulus of 11.5, were labelled as "close" and "far", respectively. Mean values and standard deviation were calculated for the second and third groups. As can be seen, no overlap is possible, even considering the limits of the standard deviation, assuring us of a separate existence. The histogram of the distance is presented in Figure 10 in which the two groups are clearly discernible.

In this figure the stars are grouped in two peaks. A Gaussian fit determined one at a distance of 1750 ± 80 pc and the other at 2430$\pm$ 194 pc. Given the uncertainties one cannot group all the stars in just one cluster because the spread would be too large. We encountered this situation before when we studied the cluster of NGC 6882/5 (Peña et al., 2008) where we found two clusters at distances of

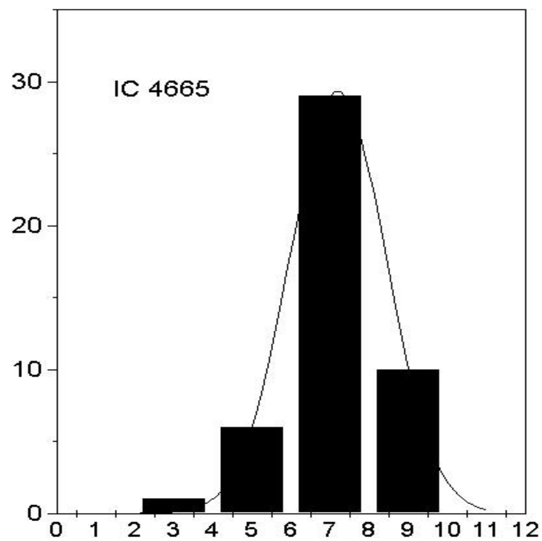

Fig. 8. Histogram of the distance modulus (X axis) of the stars in the direction of IC 4665.

289 ± 92 pc and 1019 ± 134 pc. At the bottom of each group in Table 12 we present the mean values and the standard deviation of reddening $E(b-y)$, distance modulus and distance for the stars that we consider to be members of each cluster. Unfortunately, the membership probability reported in the literature is for only five stars, none of which was measured in this paper.

In the case of the open cluster Dzim 5 it has been suggested in the literature that there is no clear evidence of the existence of the cluster. We have measured, as did Kazlauskas (2013), the fourteen brightest stars in the field. Given the limitation imposed by the telescope-spectrophotometer system, no fainter stars could be observed. In the $[m_1]$ - $[c_1]$ diagram we can see that all the stars are of spectral types F and later, and there is no evidence of earlier stars. Hence, the analysis with the prescription of Nissen (1988) has to be considered and yields the results presented in Table 13 for the five F type stars shown schematically in Figure 11. They are all located at nearly the same distance, 215 ± 45 pc, and have a [Fe/H] value of -0.14 ± 0.30. This value is close to that determined from the values reported in Column nine of Table 2 of Kazlauskas (2013). The mean values and the standard deviation of reddening $E(b-y)$, distance modulus, and distance for the stars that we consider to be members are presented at the bottom of Table 13. However, the question of the real existence of a cluster constituted by only four or five late type stars still remains.

To determine age one must first determine the temperature of the hottest main sequence stars. The

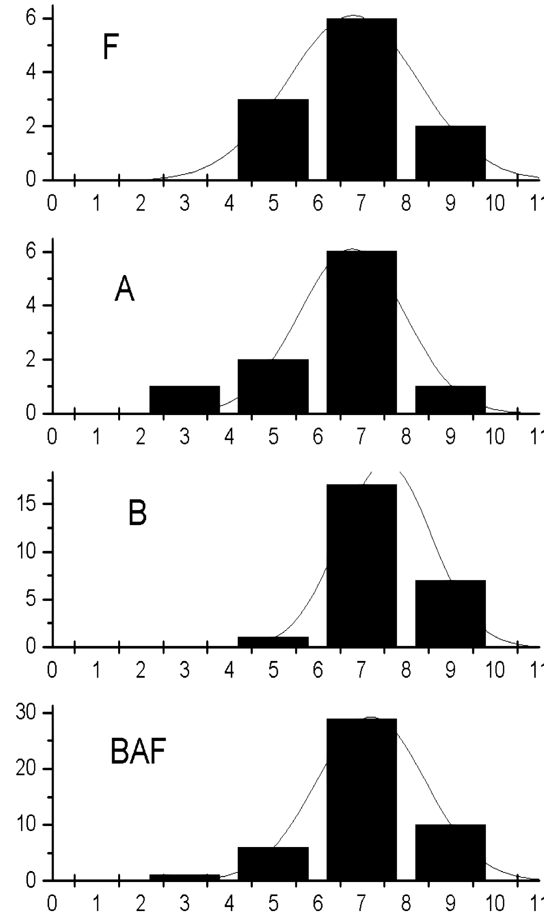

Fig. 9. Histogram of the distance modulus (X axis) of the stars in the direction of IC 4665 for each spectral type.

effective temperature of these hottest stars was calculated by plotting the location of all stars on the theoretical grids of Lester, Gray and Kurucz (1986, hereinafter LGK86), after we calculated the unreddened colors (Figures 15, 16 and 17) for the correct chemical composition of the considered model.

For IC 4665 we have utilized the c_0 vs. Hβ diagram of LGK86 which allows the determination of the temperatures of the hottest star with an accuracy of a few hundreds of degrees (Figure 15). This star is W62 at 16900 K.

For NGC 6871 we had to consider the existence of the two overlapped clusters. For the closest, the two hottest stars over the MS are stars W11 and W15 of 25000K and 23000K, whereas for the other cluster, the hottest star on the MS is star W13 at 35000K (Figure 16). For Dzim 5, Figure 17 represents the unreddened points in the $(b-y)$ vs. c_0 diagram. The hottest star, W15 has a temperature of 6,200 K.

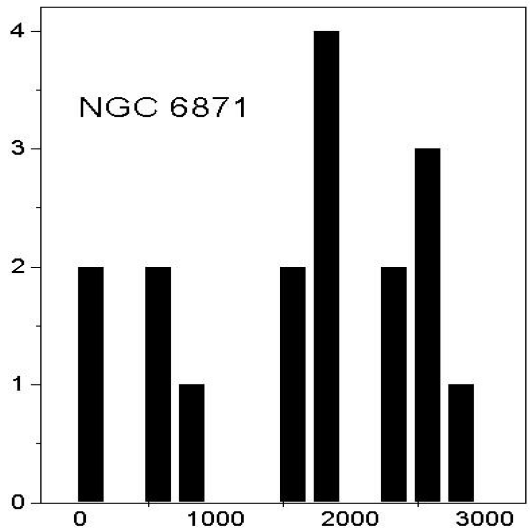

Fig. 10. Histogram of the distance (pc) (X axis) of the stars in the direction of NGC 6871.

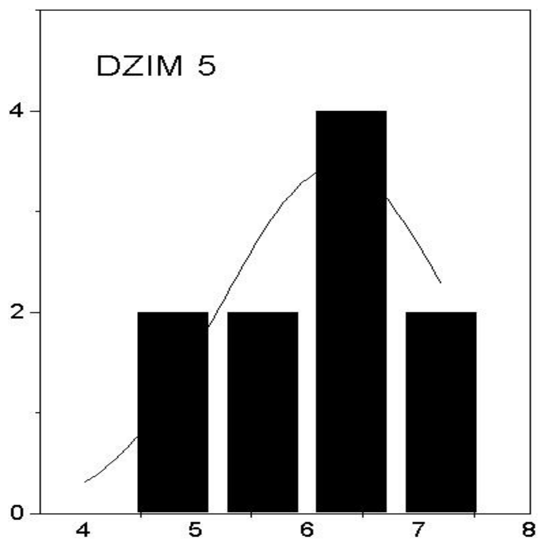

Fig. 11. Histogram of the distance modulus (X axis) of the stars in the direction of Dzim 5.

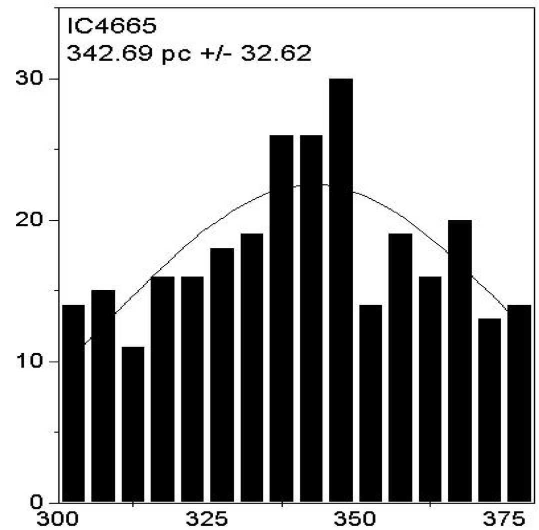

Fig. 12. Histogram of the distances (pc) to the cluster IC 4665 determined through the GAIA Data Release 2 (GAIA DR2).

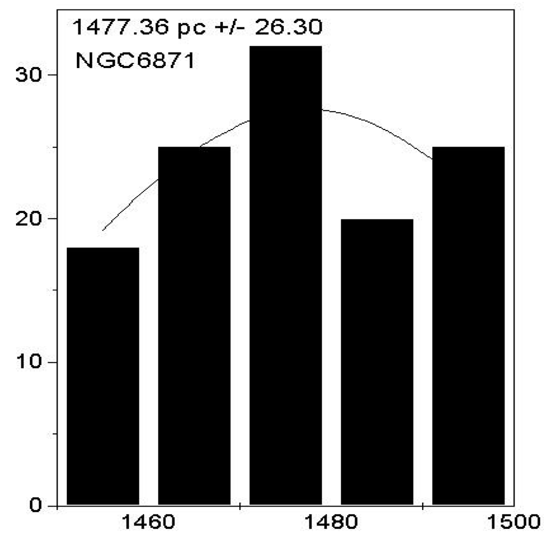

Fig. 13. Histogram of the distances (pc) to the cluster NGC 6871 determined through the GAIA Data Release 2 (GAIA DR2).

Once the membership and effective temperature have been established, age is determined through the calibrations of Meynet, Mermilliod & Maeder (1993) as a function of the temperature:

- if the $\log T_e$ is in the range [4.25, 4.56],

$$\log_{10}(\text{age}) = -.3499 \times \log T_e + 22.476, \quad (1)$$

- if the $\log T_e$ is in the range [3.98, 4.25],

$$\log_{10}(\text{age}) = -3.611 \times \log T_e + 22.956, \quad (2)$$

- if the $\log T_e$ is in the range [3.79, 3.98],

$$\log_{10}(\text{age}) = 15.142\,[\log_{10}(T_e)]^2 - 122.810\log_{10}(T_e) + 257.518\ . \quad (3)$$

The location of the member stars in the isochrones provided by WEBDA has also been done. Since this figure is presented in the customary HR diagram $(B-V)$ vs. V those stars that were determined to be members have been identified in the data set of Hogg & Kron (1955). The chemical composition that best fits the data is 0.019. This model correctly describes the evolutive path. The other impor-

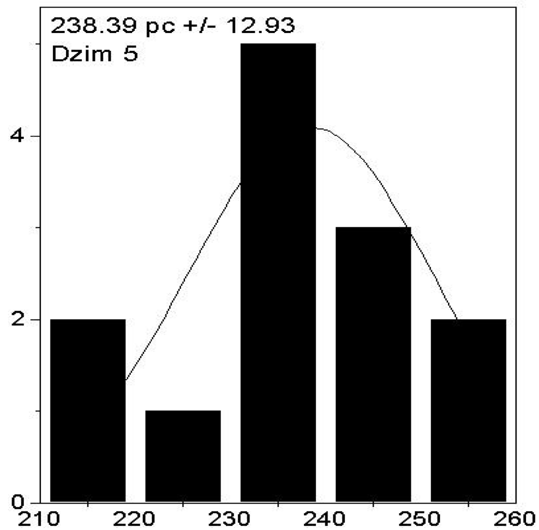

Fig. 14. Histogram of the distances (pc) to the cluster Dzim 5 determined through the GAIA Data Release 2 (GAIA DR2).

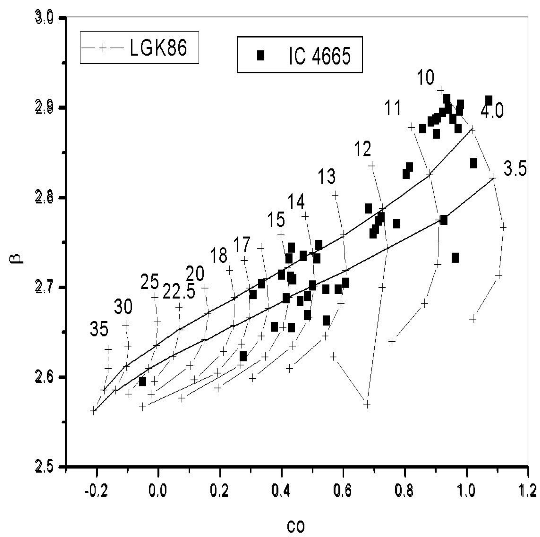

Fig. 15. Location of the unreddened points of IC 4665 (filled squares) in the LGK86 grids. The values of the effective temperature, indicated in thousands Kelvins as a vertical dashed line and surface gravity, indicated as a horizontal straight line, can be measured.

tant parameters from the isochrone plot of Webda (Geneva) are a distance modulus of 7.73, $E(B-V)$ of 0.174, Av of 0.158 and a log age of 7.65.

In the case of NGC 6871, WEBDA does not report metallicity values and all the stars measured turned out to be early type stars. There was one star of spectral type A which does not belong to the cluster and two more of spectral type G or later for which there is no calibration. In view of this we

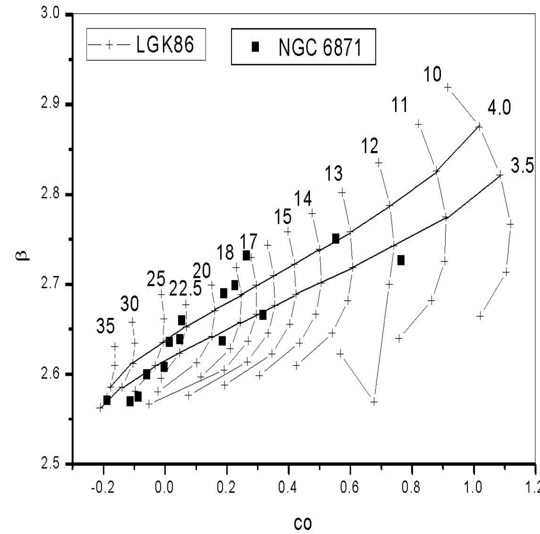

Fig. 16. As in Figure 15 but for NGC 6871. Location of the unreddened points of the open cluster NGC 6871 (filled squares) in the LGK86 grids. As in Figure 15 the values of effective temperature indicated in thousands Kelvins as a vertical dashed line and surface gravity, indicated as a horizontal straight line, can be measured.

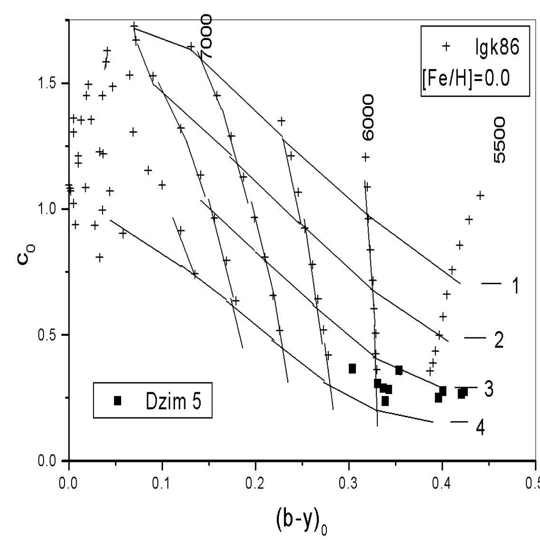

Fig. 17. Location of the unreddened points of Dzim 5 (filled squares) in the LGK86 grids. Values of effective temperature, in Kelvins, and surface gravity are indicated.

considered a solar composition. The location of the stars in the LGK86 grids for this cluster is presented in Figure 16. The value of log age is presented in Table 14.

TABLE 14

DISTANCE AND AGE DETERMINATION FOR EACH CLUSTER

Cluster	Distance	Star	T_e	$\log T_e$	log age
	pc		K		
IC 4665	343 ± 71	62	16000	4.204	7.775
NGC 6781-I	1713 ± 123	5,7	25000	4.398	7.088
NGC 6781-II	2464 ± 156	4	35000	4.544	6.576
Dzim 5	152 ± 32	15	6200	3.792	9.550

5. DISTANCES TO THE CLUSTERS DETERMINED THROUGH THE GAIA DATA RELEASE 2 (GAIA DR2)

The above mentioned membership determined through the distance distribution on a histogram has been tested on the open cluster Alpha Per (Peña & Sareyan, 2006). However, this determination can be verified using more modern and advanced techniques such as GAIA Data Release 2 for 2018, providing astrometric data from more than a billion sources. The distances cannot be determined merely by inverting the parallax since going from parallax to distance is not trivial. The way to obtain the pure geometric distance is by considering a Bayesian statistical analysis (Luri et al. 2018). Once the parallax has been obtained, the parallax data can be used to infer geocentric distance taking this correction to account for the non-linearity of the transformations and the asymmetry of the resulting probability distribution as mentioned by Bailer-Jones (2018). In their paper they present a set of data of 1.3 billion stars with corrected pure geometric distances from the GAIA DR2 sources.

The data of the 1.3 billion sources are now accessible in the GAIA archive (`http://gea.esac.esa.int/archive/`) and were used in the present paper to look for the existence of the studied clusters, IC 4665, NGC 6871 and Dzim 5. To do so, we performed a cone search centered on the coordinates (RA/Dec) of the cluster with a radius greater than that assumed by Webda for the cluster, using the whole sample and taking 20 as a magnitude limit.

In the case of NGC 6871 the radius was chosen through visual inspection. In Table 15, Column 1 lists the ID, Column 2, the coordinates from Webda, Column 3, the assumed cluster diameter in arcmin, Column 4, the considered radius which contains the whole cluster, Column 5 the number of stars contained in the cone and Column 6 the distance in parsecs in the histograms (Figures 12, 13 and 14). The uncertainties are the RMS error of the fit. These results are also presented in Table 15 for IC 4665, NGC 6871 and Dzim 5, respectively.

The comparison of our determined distance measures with those in the Gaia catalog DR2 were also done on a star-by-star basis. These are presented in Tables 16, 17 and 18 for IC 4665, NGC 6871 and Dzim 5, respectively; Column 1 lists the ID of Webda, Column 2, the ID of GAIA DR2 ordered by the distance obtained in the present paper (Column 3). Column 4 presents GAIA's distance and the final column lists the assumed membership in the present paper.

6. DISCUSSION AND CONCLUSIONS

Our study of the three clusters through $uvby-\beta$ photoelectric photometry has been done and led us to derive interesting results. The first cluster, IC 4665, is a well-known cluster which has served as a prototype for classical works. This allowed us to do two things with our photometry. First, to corroborate the goodness of our photometric values; and second, with an extended basis, to corroborate the previous findings.

Although the observational data of NGC 6871 are scarce, with the GAIA DR2 results we were able to confirm the existence of two accumulations of stars, which, as in the case of NGC 6882/5 (Peña et al. 2008), show up as two distinct clusters in the line of sight. However, there are some differences in interpretation between the GAIA DR2 results and those we obtained through Strömgren photometry: W11, W15, W21, W24, and W31 are placed in the nearest cluster, while we put them in the farthest one; W7 appears in the farthest cluster with the GAIA DR2 results, but in the nearest with ours. There is also the case of W25. We discarded it as a member of either cluster, but GAIA places it in the nearest cluster. As was mentioned in § 3, in our analysis this star presents a high dispersion, as can be seen in Table 9, and this dispersion could have caused the differences in interpretation. There is one star, W101, which we did not observe. We listed it in Table 9 but different sources assigned very discordant values to its magnitude. In view of these discrepancies we did not consider it in the analysis. At any rate, there are two clusters in the same direction regardless of the distance determination technique.

The final cluster, Dzim 5, as here stated and according to previous works, might not be a cluster despite the claim of its existence by Dolidze & Jimsheleishvili (1966). Our findings are puzzling. We found that there is a small group of five or six stars, basically at the same distance, and all are of

TABLE 15

DISTANCES TO THE CLUSTERS DETERMINED THROUGH GAIA DATA RELEASE 2

ID	RA/Dec	Assumed cluster diameter	Used radius	No. Stars in Cone	GAIA distance
	hh:mim:sec deg:min:sec	arcmin	arcmin		pc
IC 4665	17:46:18 +05:43:00	45	30	33101	342 ± 32
NGC 6871	20:05:59 +35:46:36	18	11	19032	1477 ± 26
DZIM 5	16:27:24 +38:04:00	27	15	1113	238 ± 13

TABLE 16

IC 4665, STAR BY STAR DISTANCE COMPARISON BETWEEN GAIA AND THE PRESENT PAPER

ID WBDA	ID GAIA	Dst PP (pc)	Dst GAIA (pc)	Membership PP
68	4473856639546336640	69	119	N
47	4474127634803192448	81	110	N
56	4474079015773324928	143	155	N
67	4474058984045718400	231	313	N
50	4473670783424690816	247	326	M
66	4474073518215093632	270	340	M
62	4474048263807307776	289	272	M
43	4474064447244215168	301	357	M
65	4474102036798006912	311	343	M
49	4474066504530306688	333	339	M
64	4474059087124940672	335	352	M
76	4474053727005666816	339	307	M
73	4474061835904011776	352	362	M
58	4474071147393145344	364	347	M
82	4474057437857436032	373	322	M
89	4474081588455448320	398	336	M
72	4474106297406021632	430	336	M
44	4474062523098811904	459	616	N
81	4473855501377642368	619	455	N
Mean		334	334	
Std dev		51	24	

late spectral type. There is no indication of early type stars, present or past. The comparison with GAIA DR2 confirms the validity of our results since of the five distances determined, four are of the same order of magnitude.

We have compared our findings with those of GAIA DR2. For IC 4665 the results are amazingly coincident, corroborating the goodness of the $uvby - \beta$ photometric calibration. For NGC 6871 we found two clusters in the same direction, such as for NGC 6882/5 (Peña at al. 2008). Our comparison with GAIA DR2 is in accordance with the existence of two clusters. Star W25 gives very different results: we determined a distance of 168 pc whereas GAIA fixed its distance at 1682 pc. Stars W4, W5, W7 and W101 do not have distances reported by GAIA. Finally, for Dzim 5 there is an accumulation of a few stars at the same distance determined by GAIA DR2, within the uncertainties. These results, particularly IC 4665, prove, as we did for the open cluster Alpha Per, that the results inferred from $uvby - \beta$ photoelectric photometry are trustworthy.

Unveiling the truth of open clusters is not a simple task. The nitty gritty obviously rests on determining the membership of the stars to the cluster. $uvby - \beta$ photoelectric photometry is a well-known canonical method. Results like those of the open cluster Alpha Per (Peña & Sareyan, 2006) ensure the credibility of the results. One of these open clusters presented here, IC 4665, which has been well studied, corroborates the goodness of our results since it gives the same results as those previously determined through different methods. There are other clusters

TABLE 17

NGC 6871, STAR BY STAR DISTANCE COMPARISON BETWEEN GAIA AND THE PRESENT PAPER

ID Webda	ID GAIA (DR2)	Dst PP (pc)	Dst GAIA (pc)	Membership (GAIA)
12	2059099444490880000	134	167	NM
25	2059076041181621888	168	1819	close
37	2059070681062443904	541	409	NM
10	2059101604826977152	621	557	NM
8	2059075839349023104	1574	1754	close
27	2059112913509204352	1581	1626	close
13	2059071887978880512	1734	1870	close
7	2059073159271061632	1806	2439	far
5	2059075873709364864	1886	1754	close
31	2059095424401407232	1924	1459	close
24	2059076041181622144	2208	1570	close
11	2059075255233453824	2354	1777	close
14	2059076389104969856	2459	2158	far
15	2059099856807768960	2483	1748	close
21	2059075804989882496	2549	1711	close
4	2059070135632404992	2711	1936	far
Mean (close)			1709	close
Std dev			123	
Mean (far)			2178	far
Std dev			252	

TABLE 18

DZIM 5, STAR BY STAR DISTANCE COMPARISON BETWEEN GAIA AND THE PRESENT PAPER

ID Webda	ID GAIA	Dst PP (pc)	Dst GAIA (pc)	Membership PP
7	1331325688646042624	161	247	N
8	1331330292850992256	190	246	N
12	1331988758581273600	203	316	M
14	1332086683834797312	247	360	M
3	1332082427523975168	274	790	M
Mean		241	489	
Std dev		36	262	

which apparently are well-observed, like NGC 6871 but that, when carefully analyzed, reveal that there are few observations (only twenty-three stars with full $uvby-\beta$ photoelectric photometry). What was unexpected was the presence of not one, but of another cluster in the same line of sight; the clusters are at distance modulus of 11.2 ± 0.1 and 12.0 ± 0.1. The histogram of the distances to the cluster determined through the GAIA Data Release 2 (GAIA DR2) suggests the presence of another peak. Finally, with respect to Dzim 5 we only add little to the puzzle beyond the categorical statement of its existence by Dolidze & Jimsheleishvili (1966) to the denial of its existence by Kazlauskas et al., (2013), we could not add much. The results of this study showed that the m_1 and c_1 indexes of provided by Kazlauskas et al. had serious errors that could have led the authors to erroneous conclusions. Our findings suggest the presence of a small group of only late type stars at the same distance, a cluster by definition, but we could not find any vestiges of early type stars either in the present or in the past. The GAIA DR2 results also show an accumulation of stars at 238 ± 13 pc, close to the value determined in the present work (152 ± 32 pc).

We would like to thank the staff of the OAN for their assistance in securing the observations. This work was partially supported by Papiit IN104917, IG100620 and PAPIME 113016. ARL & CVR thank the IA-UNAM for the opportunity to carry out the observations. Proofreading was done by J. Miller. C. Guzmán, F. Salas, B. Juarez, C. Villarreal, J. Calderón, J. Guillen and J. Díaz assisted us at different stages. Comments and suggestions of an anonymous referee improved the paper. This research has made use of the Simbad databases operated at CDS, Strasbourg, France and the NASA ADS Astronomy Query Form.

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