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ON THE NATURE OF THE OPEN CLUSTERS IN THE DIRECTION OF NGC 6882/5

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RESUMEN

Se presenta fotometría fotoeléctrica $uvby-\beta$ del cúmulo abierto NGC 6882/5. Mediante la ya probada técnica fotoeléctrica de determinación de distancias, encontramos que existen al menos dos acumulaciones diferenciables de estrellas en la dirección del cúmulo. Se lleva a cabo una breve discusión sobre la naturaleza de las estrellas previamente determinadas como variables.

ABSTRACT

Unpublished $uvby-\beta$ photoelectric photometry of the open cluster NGC 6882/5 is presented. Utilizing already tested distance determinations through photometric techniques, it is found that there are at least two distinct star accumulations in the direction of the open cluster NGC 6882/5. A brief discussion is made of the nature of the previously found short period variables.

Key Words: open clusters and associations: general — open clusters and associations: individual (NGC 6882/5) — stars: variables — techniques: photometric

1. MOTIVATION

As has been stated by Strobel (1992), *"young clusters with turn-off ages around* 1.0×10^7 *yr seem to offer a special opportunity to gain insight into the process of their formation"*; he later says that *"the wide variety of structures of the upper parts of the C-M diagrams and of the luminosity functions of young open clusters is however difficult to explain exclusively by their different evolutionary stages. Such structures can be caused also by differences in initial mass functions (IMF) and/or age spread in the cluster formation"*. He later claims that *"it seems difficult to reproduce the C-M diagrams of many young clusters with simultaneous formation of all their members... Moreover, it seems possible that clusters consist of sequentially formed subgroups differing also in their mass range"*. However, the above assertions might be disputable if the stars do not turn out to belong to the cluster.

NGC 6882/5 has been a subject of innumerable studies. For example, Strobel (1991) has assigned to it a [M/H] of −0.20, an age of 1.0×10^8 yr and a distance to the galactic center, Rgc of 8.2 kpc. Luck (1994), based on the spectroscopy of only two stars, determined a [M/H] of −0.02. Membership of 17 stars to the cluster was assigned by Geisler (1988) through radial velocity measurements. Finally, the cluster compilation of Lang (1991) gives the following data for NGC 6885: E_{B-V} of 0.08, a radius of 0.6 pc and a distance at 590 pc, whereas Webda (Paunzen & Mermilliod 2007) does not list any characteristics such as distance, reddening, DM, age or metallicity for this cluster.

In addition to cluster membership, some new short period variable stars in the direction of the cluster were previously discovered (Peña, Peniche, & Díaz-Martínez 1990) and, since the present study is based on Strömgren photometry, it is possible to determine the distances to each star individually.

2. OBSERVATIONS

All the observations were carried out at the Observatorio Astronómico Nacional at San Pedro Mártir, Mexico with the 150 cm telescope equipped with a spectrophotometer. The data were acquired

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in three seasons: July–August, 1986 (four nights); June, 1997 (six nights) and July, 2000 (four nights). The program stars in the 1986 season were selected within the capability limits of the telescope-photometer system, which is around magnitude 14. The stars were selected utilizing the ID of Hoag et al. (1961) trying to observe all the stars outwards in concentric circles of 5 arcmin from the center. In the other two seasons we tried to observe the stars that still remained unobserved in the first run. The photometric system utilized has the advantage that the *uvby* photometry is acquired simultaneously and the N and W filters that define Hβ almost simultaneously. The reduction procedure was done with the numerical packages NABAPHOT (Arellano-Ferro & Parrao 1988) and DAMADAP (Parrao 2000) which reduce the data into a standard system. The chosen system was that defined by the standard values of Olsen (1983) and the transformation equations are those defined by Crawford & Barnes (1970) and by Crawford & Mander (1966), although for the standard bright stars some were also taken from Blumberg & Boksenberg (1996, the Astronomical Almanac). In these equations the coefficients D, F, H and L are the slope coefficients for $(b-y)$, m_1, c_1 and β, respectively. B, J and I are the color term coefficients of V, m_1, and c_1.

The procedures in both the observations and the reduction were the same in the three seasons. Each measurement consisted of five ten-second integrations of each star and one ten-second integration of the sky for the *uvby* filters and for the narrow and wide filters. Individual uncertainties were also determined by calculating the standard deviations for a sample of the stars. The percent error in each measurement is of course a function of both the spectral type and the brightness of each star, but they were observed long enough to secure enough photons to get a S/N ratio of accuracy of $N/\sqrt{N}$ of 0.01 mag in all cases; the accuracy in time is 0.0024 d. A set of standard stars was observed to transform the instrumental observations into the standard system. The final accuracy of the season has been obtained from a direct comparison of the photometric values from the standard stars compared to the values from the literature; this is shown in Figure 1 in which the x axis plots the literature values and the y axis the magnitude or color index difference between those values obtained after the transformation into the standard system and those of the literature. Only one star, HD 125607, shows anomalous behaviour in both the m_1 and the c_1 indexes. We call attention to the large range in all indexes.

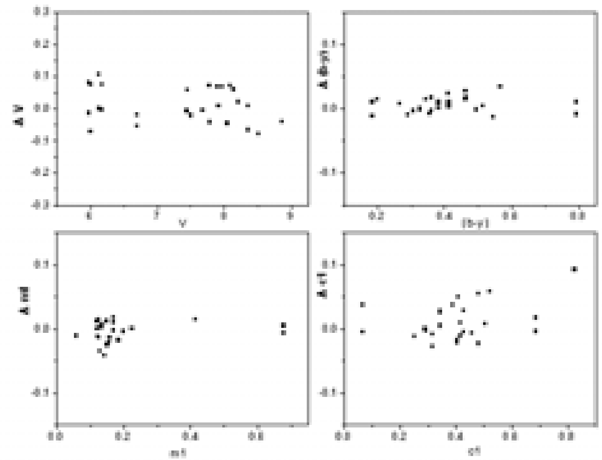

Fig. 1. Residuals between the derived and the standard values as a function of the index.

The first season was from July 26 to August 4, 1986. The obtained coefficients in the standard system of the whole season are reported in Table 1 along with those of the other seasons. The uncertainties of the 1986 season were determined from the differences between the derived magnitude of the 26 standard stars vs. reported values in the literature. The average values of such differences are $\Delta(V, b-y, m_1, c_1) = (0.008, 0.005, -0.004, 0.012)$.

The linear fit between the values in the literature and those obtained from the transformations was evaluated for the standard stars. The linear regression $Y = A + B * X$ gave the following coefficients and correlation coefficients (A, B, R): for V (−0.1144, 1.0148, 0.9983), for $b-y$, (0.0004, 0.9859, 0.995) for m_1, (0.0039, 1.0134, 0.9869) and for c_1, (0.1700, 0.9232, 0.967) which give a measurement of the confidence of the reported values. The transformation coefficients and accuracies of the other seasons, June, 1997 and July, 2000, have been reported elsewhere (Peña et al. 2002, 2003) and will not be presented here in detail, only the results. The photometric values of each season were, thus, calculated independently and later, for those problem stars with multiple observations, mean values were calculated. The cross interrelationships among the three seasons were calculated and gave the linear fits listed in Table 2 in which three discordant points were discarded.

The final averaged photometric values of the 106 measured stars are presented in Table 3. The ID numbers for each star were taken from Webda although a few stars were observed that have no Webda ID identifier; these are reported by their

TABLE 1

TRANSFORMATION COEFFICIENTS OBTAINED FOR THE OBSERVED SEASONS

Season	B	D	F	J	H	I	L
1986	−0.0355	0.9547	1.0469	0.0412	1.0052	0.0985	1.4752
1997	0.0193	1.0192	1.1620	0.1307	1.0765	0.1828	1.2310
2000	0.0110	0.9840	1.0880	0.0100	0.999	0.1050	1.2770

TABLE 2

CROSS RELATIONS BETWEEN THE THREE OBSERVED SEASONS

$V_{2000} = 0.03907 + 0.99263 * V_{1997}$	0.9911	0.11355
$b - y_{2000} = 0.01495 + 1.01821 * b - y_{1997}$	0.99921	0.015
$m_{12000} = -0.03427 + 1.04873 * m_{11997}$	0.99685	0.01816
$c_{12000} = -0.05389 + 1.03063 * c_{11997}$	0.98314	0.06015
$\beta_{2000} = 0.01459 + 1.00362 * \beta_{1997}$	0.94309	0.03844
$V_{2000} = 0.17307 + 0.98874 * V_{1986}$	0.99664	0.13374
$b - y_{2000} = -0.00261 + 1.04099 * b - y_{1986}$	0.99855	0.01759
$m_{12000} = -0.00675 + 0.95409 * m_{11986}$	0.99753	0.01396
$c_{12000} = -0.06178 + 1.13007 * c_{11986}$	0.99106	0.04281
$\beta_{2000} = 0.45097 + 0.83424 * \beta_{1986}$	0.98025	0.02412
$V_{1997} = 0.10816 + 1.00292 * V_{1986}$	0.99505	0.16502
$b - y_{1997} = 0.01853 + 1.02121 * b - y_{1986}$	0.99328	0.02598
$m_{11997} = 0.03210 + 0.87475 * m_{11986}$	0.9804	0.03678
$c_{11997} = -0.02495 + 1.10568 * c_{11986}$	0.99105	0.03877
$\beta_{1997} = 0.46614 + 0.82128 * \beta_{1986}$	0.89558	0.05283

Webda coordinates. Due to the fact that the program stars were observed with the aim of acquiring as many data as possible, there were only a few that were observed in the three seasons (fifteen) and 46 which were observed twice; the rest, (46) were observed only once. The standard deviations of those stars with three measurements were calculated; we call attention to the large discrepancies for the star W216 which had apparent magnitude values of 10.198, 10.122 and 9.813 in 1986, 1997 and 2000 respectively, discrepancies that are above the expected uncertainties. The fact that each season has completely discordant values forces us to assume an either pulsating or eclipsing variable nature of the star. In an analogous situation, although not as conspicuous is W11. Continuing with Table 3, Column 2 lists the V magnitude, Columns 3 to 5 the color indexes $(b - y)$, m_1 and c_1; Column 6 the Hβ value, Column 7 the category of the photometrically determined "spectral type" to which the star has been assigned, either B (B or early A), or A (late A and F); those stars that do not belong to either of these have been lumped in category "G", late type stars. The next column lists the number of observations for each star. For those stars with three observations, the last columns list the standard deviations in the following order: V, $b - y$, m_1, c_1 and β.

A comparison was made with the Webda compilation. However, since basically no previous Strömgren photometry had been done on this cluster, the comparison was made using the existing UBV photometry. The intersection of both photometric sets includes 48 stars in the V range from 6 to almost 15 magnitude and in the $B-V$ and $U-B$ color indexes from −0.5 to 1.4 and 1.5 mag, respectively. All in all, there were five stars which were openly discordant with exceedingly large differences in V magnitude: W10, W18, W37, W67 and W73 in all groups and W31 in the $B - V$ vs. $b - y$ indexes. The linear fit for all the sets, excluding these stars, gave a more than adequate correlation coefficient of 0.999 and 0.97 in the V and $B - V$ vs. $b - y$ index.

TABLE 3

$uvby-\beta$ PHOTOELECTRIC PHOTOMETRY OF THE STARS IN THE DIRECTION OF NGC 6882

Webda	$\langle V\rangle$	$\langle b-y\rangle$	$\langle m_1\rangle$	$\langle c_1\rangle$	$\langle\beta\rangle$	Spectral type	
						Photometric	Webda
1	5.328	0.841	0.753	0.097	2.612	G	K2III
3	6.466	0.036	0.136	0.749	2.629	BA	B7IV
5	7.65	−0.006	0.087	0.642	2.721	BA	B8III
6	8.589	0.664	0.55	0.29	2.577	G	K2III
8	9.201	0.301	0.152	0.392	2.641	AF	F6V
9	9.261	0.165	0.204	0.72	2.799	AF	A7III
10	11.522	0.354	0.08	1.075	2.765	AF	A9III
11	9.485	0.754	0.62	0.229	2.586	G	
16	9.851	0.4	0.146	0.452	2.623	AF	
17	9.971	0.369	0.187	0.393	2.617	AF	
18	12.902	0.383	0.148	0.687	2.732	AF	
19	10.225	0.264	0.182	0.854	2.801	AF	
20	10.367	0.051	0.215	0.996	2.899	AF	
21	10.385	0.06	0.216	0.949	2.924	AF	A1V
24	10.849	0.293	0.141	1.032	2.765	AF	
25	10.523	0.35	−0.054	0.188	2.592	BA	
27	10.545	0.206	0.191	0.663	2.808	AF	
28	10.523	0.097	0.125	1.027	2.872	BA	
30	10.534	0.091	0.13	1.045	2.856	AF	
31	10.86	0.537	0.347	0.285	2.569	G	
33	10.779	0.22	0.167	0.595	2.723	AF	
35	10.821	0.39	0.186	0.297	2.602	AF	
36	11.836	0.331	0.171	0.347	2.629	AF	
37	11.806	0.261	0.134	0.7	2.77	AF	
39	11.037	0.344	0.001	0.689	2.795	BA	
40	11.241	0.264	0.148	0.534	2.722	AF	
41	11.278	0.369	−0.035	0.64	2.709	BA	
43	11.401	0.363	−0.038	0.624	2.717	BA	
45	11.625	0.112	0.223	0.892	2.893	AF	
52	11.963	0.338	0.187	0.33	2.633	AF	
54	12.357	0.379	−0.022	0.827	2.715	BA	
55	12.453	0.404	−0.013	0.703	2.671	BA	
56	12.502	0.419	0.234	0.292	2.626	AF	
57	12.546	0.38	0.135	0.459	2.642	AF	
58	12.55	0.473	0.187	0.426	2.625	AF	
59	12.935	0.397	0.019	0.866	2.906	BA	
60	12.919	0.396	0.026	0.823	2.687	BA	
61	12.975	0.411	−0.053	0.76	2.719	BA	
62	12.905	0.399	0.01	0.868	2.844	BA	
63	12.879	0.389	−0.016	0.854	2.842	BA	
64	12.868	0.536	0.068	0.944	2.789	AF	
65	13.049	0.409	0.045	0.864	2.909	BA	
66	13.332	0.422	0.118	0.36	2.624	AF	
67	13.534	0.456	−0.026	0.964	2.959	BA	
70	13.911	0.524	0.039	0.822	2.818	AF	
71	13.78	0.382	0.143	0.322	2.7	AF	
72	14.203	0.53	−0.031	1.026	2.894	BA	
73	12.967	0.361	0.006	0.773	2.727	BA	
77	12.798	0.489	0.273	−0.01	2.592	G	
78	9.846	0.89	0.614	0.245	2.587	G	
79	13.303	0.517	−0.077	0.899	2.861	BA	
81	11.834	0.34	0.133	0.553	2.824	AF	
82	12.757	0.456	0.143	0.367	2.606	AF	
85	10.859	0.121	0.128	0.932	2.868	BA	
86	12.2	0.302	0.081	0.796	2.778	BA	
87	12.923	0.411	−0.064	0.846	2.337	BA	
88	12.994	0.303	0.176	0.362	2.565	G	
90	10.128	1.212	0.504	0.182	2.623	G	
92	13.18	0.436	0.06	1.061	2.757	AF	
93	12.643	0.414	−0.049	0.974	2.916	BA	

TABLE 3 (CONTINUED)

Webda	⟨V⟩	⟨b − y⟩	⟨m_1⟩	⟨c_1⟩	⟨β⟩	Spectral type	
						Photometric	Webda
94	11.757	0.406	−0.055	0.727	2.818	BA	
95	11.022	0.366	−0.069	0.642	2.671	BA	
98	11.544	0.437	−0.051	0.761	2.711	BA	
99	11.28	0.263	0.152	0.549	2.705	G	
100	11.713	0.622	0.221	0.439	2.589	G	
101	11.936	0.544	−0.073	0.444	2.606	G	
103	10.715	0.425	0.211	0.183	2.595	AF	
105	10.258	0.115	0.192	0.888	2.84	AF	
106	11.3	0.137	0.189	0.895	2.885	AF	
107	10.551	0.223	0.204	0.888	2.816	AF	
108	11.529	0.423	0.206	0.342	2.62	AF	
121	9.447	0.474	0.286	0.486	2.574	G	
122	11.525	0.372	0.187	0.324	2.632	AF	
123	8.975	0.218	0.182	0.695	2.721	AF	
124	10.793	0.359	−0.034	0.792	2.68	BA	
127	12.088	0.334	0.152	0.434	2.672	AF	
129	13.204	0.715	0.029	0.649	2.731	AF	
134	11.258	0.264	0.155	1.052	2.859	AF	
135	12.039	0.329	0.214	0.337	2.569	G	
138	13.541	0.39	0.152	0.371	2.734	AF	
140	12.975	0.447	−0.031	0.743	2.79	BA	
141	12.331	0.48	−0.056	0.904	2.781	BA	
146	12.489	0.446	−0.018	0.754	2.715	BA	
158	11.632	0.451	0.11	0.49	2.627	AF	
163	13.747	0.537	−0.006	0.709	2.722	BA	
165	11.764	0.278	0.181	0.775	2.726	AF	
174	13.203	0.399	0.02	0.97	2.976	BA	
177	11.645	0.315	0.147	0.708	2.682	AF	
179	12.098	0.41	0.233	0.358	2.518	G	
182	13.611	0.396	0.047	1.093	.	BA	
185	13.422	0.539	0.191	0.279	2.644	AF	
187	13.383	0.451	0.075	0.491	2.691	AF	
189	12.693	0.486	−0.05	0.797	2.799	BA	
197	11.758	0.338	0.162	0.412	2.665	AF	
198	10.477	1.219	0.729	0.39	2.565	G	
202	13.278	0.482	−0.009	0.989	2.916	BA	
206	11.661	0.238	0.151	0.734	2.754	AF	
216	9.769	1.263	0.644	0.017	2.602	G	
"−10.9,−4.5"	13.697	0.506	0.104	0.502	2.7	AF	
"12.0,−9.8"	13.285	0.446	−0.075	0.775	2.849	BA	
"13.5,−2.5"	14.114	0.56	0.01	0.928	2.983	BA	
"16.5,−0.5"	13.431	0.349	0.257	0.188	2.451	G	
"−23.9,−4.8"	13.087	0.471	0.106	0.689	2.721	AF	
"−26.9,−9.0"	11.98	0.432	0.227	0.262	2.56	G	
"−7.6,−3.3"	13.838	0.489	0.141	0.366	2.532	G	
"−9.6,16.6"	12.531	0.411	0.235	0.245	2.524	G	

The $U-B$ vs. $u-b$ index gave a poorer correlation, of merely 0.89 in R and a larger scatter due mainly to noise in the u filter.

Since the submission of this paper, Hintz, Rose, & Michael (2005) published a very interesting article on the variables in the field of NGC 6882. They also published observations in the V, R, I filters of 94 stars to which a comparison is possible and desirable. However, they used their own nomenclature, although in some cases they also reported the Hoag et al. (1961) ID numbers. The sample in the intersection of their reported stars with that of Webda includes of 29 entries. A linear fit in the V filter gives $V_{\rm H\&R} = 0.186 + 0.983 * V_{\rm Webda}$. A careful comparison between their ID chart and that of Webda was done and the sample of stars in common with those of the present paper was extended to 27 entries. The linear fit between the two sets gave $V_{\rm pp} = -0.02236 + 1.00054 * V_{\rm H\&R}$ with a correlation coefficient R of 0.99648 and a standard deviation of 0.10661 in a large range V limits between magnitudes 9.2 and 13.5. In view of these, we are certain that our photometry, in comparison other reported photometries, is correct.

The intersection of the data in the present paper (107 entries) with those of Webda comprises a larger sample, 47 entries. There were a few stars, (5) which have discordant values in the apparent magnitude difference $V_{\rm pp} - V_{\rm Webda}$. Given the consistency among our three seasons, and the correctness between our values and those in the literature, H&R and Webda's, we could imply that these might be variable stars. However, we call attention to the fact that these stars were observed but once, and all in the 1997 season. Nevertheless, with most stars in the same season there were no large discrepancies. We have opted then to include them with the values we obtained, although caution must be taken. The fact that these five stars are discordant, we feel, does not change our conclusions given that the discordant stars are merely a 5 percent of the large sample of the 105 observed stars.

3. ANALYSIS

The most important parameter determined when studying the nature of a cluster is, beyond a doubt, the membership of each star to the cluster. Cluster membership can be established using the advantages of Strömgren photometry with calibrations made by Nissen (1988) based on calibrations of Crawford (1975, 1979) for the A and F stars and of Shobbrook (1984) for early type stars. These calibrations have been already employed and described in previous analyses of open clusters (Peña & Peniche 1994).

The determination of physical parameters such as effective temperature and surface gravity has been done in the present study through the Strömgren photometric data reduced to the standard system, once corrected for interstellar extinction. If the photometric system is well-defined and calibrated, it will provide an efficient way to investigate physical conditions. A comparison with theoretical models, such as those of Lester, Gray, & Kurucz (1986, hereafter LGK86), allows a direct comparison with intermediate or wide band photometry measured from the stars with those obtained theoretically for early type stars. LGK86 calculated grids for stellar atmospheres for G, F, A, B and O stars for the solar abundance [Fe/H] = 0.00 in a temperature range from 5500 K up to 50 000 K. The surface gravities vary approximately from the Main Sequence to the limit of the radiation pressure in 0.5 intervals in $\log g$. They also considered abundances of 0.1 solar and 0.001 solar. A comparison of the photometric unreddened indexes $(b-y)_0$ and c_0 obtained for each star with such models allows the determination of the effective temperature $T_{\rm e}$ and surface gravity $\log g$ along the cycle of pulsation.

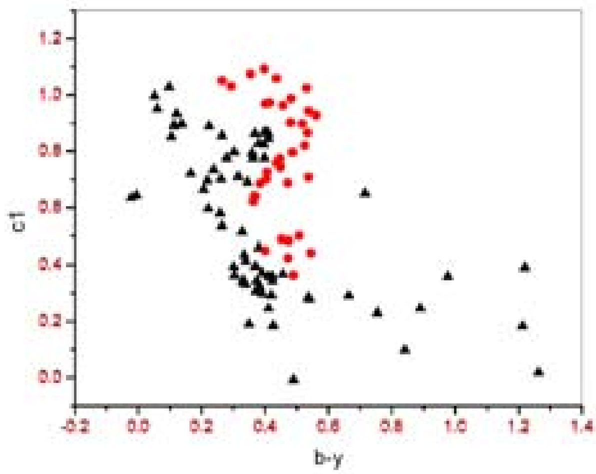

Fig. 2. Location of the measured stars in the $(b-y)$ vs c_1 diagram. The whole sample is separated into two discernible groups and marked by triangles and dots.

4. RESULTS

The analysis of the data is quite interesting. From the color diagrams $(b-y)-m_1$, $(b-y)-c_1$, $(b-y)-H\beta$ it becomes evident that there are clearly two distinct groups of stars, particularly in the $(b-y)-c_1$ diagram (Figure 2). This result is evident, although less discernible in the $(b-y)-m_1$ and also in the m_1-c_1 diagrams. The data can be divided via Figure 2 into two groups.

The determination of the reddening was done by determining, as was stated above, to which spectral class the stars belonged: early (B and early A) or late (late A and F stars) types; the later class stars (later than G) were not considered in the analysis since no reddening determination calibration has yet been developed for MS stars.

In order to determine the spectral type of each star, as a primary criteria the location of the stars in the $[m_1]-[c_1]$ diagram was employed. Further criteria were taken into account following the prescriptions of Lindroos (1980) which merely confirmed our primary criterion. In Table 3 the photometrically determined spectral class has been indicated. The application of the above mentioned numerical packages gave the results listed in Table 4 in which the ID, the reddening, the unreddened indexes, the absolute magnitude, the DM and distance, as well as the metallicity for the F stars are listed.

When histograms of the distances are drawn, as in Figure 3, one can see that most of the early type stars lie at distance centered at 1000 pc, but with a large spread towards the higher values, whereas

TABLE 4

REDDENING AND UNREDDENED PARAMETERS OF NGC 6882/5

ID	$E(b-y)$	$(b-y)_0$	m_0	c_0	β	V_0	M_V	DM	DST	[Fe/]	cluster membership	log(age)
103	0.022	0.403	0.218	0.179	2.595	10.620	6.28	4.34	74	0.100	nm	
81	0.191	0.149	0.190	0.515	2.824	11.010	5.14	5.87	149		nm	
35	0.015	0.375	0.190	0.294	2.602	10.760	4.62	6.14	169	−0.080	nm	
27	0.055	0.151	0.207	0.652	2.808	10.310	3.93	6.38	189		nearest	
17	0.015	0.354	0.191	0.390	2.617	9.910	3.43	6.48	197	0.050	nearest	
123	0.003	0.215	0.183	0.694	2.721	8.960	2.20	6.76	225		nearest	
122	0.030	0.342	0.196	0.318	2.632	11.390	4.57	6.82	232	0.210	nearest	
108	0.055	0.368	0.223	0.331	2.620	11.290	4.19	7.10	263	0.391	nearest	
185	0.191	0.348	0.248	0.241	2.644	12.600	5.24	7.36	296	0.887	nearest	
56	0.046	0.373	0.248	0.283	2.626	12.310	4.95	7.36	296	0.707	nearest	
40	0.034	0.230	0.158	0.527	2.722	11.100	3.67	7.43	306		nearest	
52	0.002	0.336	0.187	0.330	2.633	11.960	4.50	7.46	310	0.123	nearest	
138	0.151	0.239	0.197	0.341	2.734	12.890	5.42	7.47	312		nearest	
−10.9−4.5	0.309	0.197	0.197	0.440	2.771	12.370	4.83	7.54	322		nearest	
36	0.000	0.333	0.171	0.347	2.629	11.840	4.23	7.61	332	−0.079	nearest	
33	0.000	0.224	0.167	0.595	2.723	10.780	3.15	7.63	336		nearest	
197	0.049	0.289	0.177	0.402	2.665	11.550	3.85	7.70	346	0.172	nearest	
71	0.129	0.253	0.182	0.296	2.700	13.230	5.37	7.86	373	0.256	nearest	
105	0.013	0.102	0.196	0.885	2.840	10.200	2.30	7.90	381		nearest	8.86
9	0.210	−0.045	0.267	0.680	2.799	8.360	0.35	8.01	400		nearest	
107	0.101	0.122	0.234	0.868	2.816	10.120	2.03	8.09	415		nearest	8.91
127	0.056	0.278	0.169	0.423	2.672	11.850	3.70	8.14	425	0.096	nearest	
average	0.076								289	0.236		
stddev	0.085								92	0.295		
129	0.502	0.213	0.180	0.549	2.731	11.050	2.85	8.20	436		nm	
5	0.042	−0.048	0.099	0.634	2.721	7.470	−0.75	8.22	441		nm	
37	0.083	0.178	0.159	0.683	2.770	11.450	3.03	8.42	483		nm	
82	0.098	0.358	0.172	0.347	2.606	12.340	3.64	8.70	550	−0.219	nm	
158	0.132	0.319	0.150	0.464	2.627	11.070	2.26	8.81	578	−0.319	nm	
66	0.095	0.327	0.146	0.341	2.624	12.930	3.99	8.93	612	−0.367	nm	
206	0.051	0.187	0.166	0.724	2.754	11.440	2.49	8.95	618		nm	
58	0.116	0.357	0.222	0.403	2.625	12.050	3.10	8.95	617	0.428	nm	
39	0.393	−0.049	0.119	0.614	2.795	9.350	0.31	9.04	642		intermediate	8.08
187	0.205	0.246	0.137	0.450	2.691	12.500	3.45	9.05	646	−0.355	intermediate	
28	0.108	−0.011	0.157	1.006	2.872	10.060	0.99	9.07	652		intermediate	
85	0.150	−0.029	0.173	0.903	2.868	10.210	1.00	9.21	695		intermediate	
94	0.453	−0.047	0.081	0.641	2.818	9.810	0.56	9.25	709		intermediate	8.10
93	0.445	−0.031	0.084	0.890	2.916	10.730	1.43	9.30	724		intermediate	
57	0.073	0.307	0.157	0.444	2.642	12.230	2.91	9.32	732	−0.164	intermediate	
134	0.193	0.071	0.213	1.013	2.859	10.430	1.03	9.40	757		intermediate	
average	0.253								695	−0.260		
stddev	0.154								44	0.135		
174	0.430	−0.031	0.149	0.888	2.976	11.350	1.86	9.49	792		nm	
70	0.397	0.127	0.158	0.743	2.818	12.210	2.65	9.55	814		nm	
18	0.174	0.209	0.200	0.652	2.732	12.150	2.53	9.62	840		farthest	
202	0.512	−0.030	0.145	0.892	2.916	11.070	1.43	9.64	848		farthest	
13.5-2.5	0.597	−0.037	0.189	0.815	2.983	11.550	1.88	9.67	858		farthest	
67	0.488	−0.032	0.121	0.871	2.959	11.430	1.75	9.69	866		farthest	
59	0.436	−0.039	0.150	0.783	2.906	11.060	1.35	9.71	876		farthest	
−23.9−4.8	0.256	0.215	0.183	0.638	2.721	11.990	2.25	9.74	885		farthest	
65	0.448	−0.039	0.179	0.779	2.909	11.120	1.37	9.75	892		farthest	
165	0.074	0.204	0.203	0.760	2.726	11.440	1.60	9.85	932		farthest	
3	0.078	−0.042	0.159	0.734	2.629	6.130	−3.79	9.92	966		farthest	
79	0.555	−0.038	0.090	0.794	2.861	10.920	0.97	9.95	975		farthest	
64	0.398	0.138	0.187	0.864	2.789	11.160	1.12	10.04	1018		farthest	
141	0.517	−0.037	0.099	0.806	2.781	10.110	0.05	10.06	1028		farthest	
189	0.530	−0.044	0.109	0.696	2.799	10.420	0.35	10.07	1033		farthest	
61	0.407	−0.039	0.129	0.785	2.869	11.210	1.04	10.16	1078		farthest	
63	0.407	−0.039	0.129	0.785	2.869	11.210	1.04	10.17	1080		farthest	
62	0.438	−0.039	0.141	0.785	2.844	11.020	0.81	10.22	1104		farthest	
24	0.144	0.149	0.184	1.003	2.765	10.230	−0.03	10.26	1128		farthest	
12.0-9.8	0.490	−0.044	0.072	0.682	2.849	11.180	0.86	10.32	1158		farthest	
43	0.418	−0.055	0.087	0.545	2.717	9.600	−0.74	10.35	1174		farthest	8.00
41	0.422	−0.053	0.092	0.560	2.709	9.460	−0.90	10.36	1180		farthest	8.02
98	0.482	−0.045	0.094	0.669	2.711	9.470	−0.99	10.46	1234		farthest	
177	0.064	0.251	0.166	0.695	2.682	11.370	0.88	10.49	1256	0.065	farthest	
average	0.379								1019			
stddev	0.167								134			
72	0.557	−0.027	0.136	0.920	2.894	11.810	1.24	10.57	1298		nm	
140	0.494	−0.047	0.117	0.649	2.790	10.850	0.25	10.60	1319		nm	
86	0.344	−0.042	0.184	0.731	2.778	10.720	0.06	10.66	1354		nm	
16	0.475	−0.075	0.289	0.362	2.623	7.810	−2.85	10.66	1355		nm	
124	0.402	−0.043	0.086	0.716	2.680	9.070	−1.81	10.88	1499		nm	
10	0.209	0.145	0.143	1.033	2.765	10.620	−0.42	11.04	1615		nm	
146	0.492	−0.046	0.130	0.661	2.715	10.370	−0.89	11.27	1793		nm	
54	0.420	−0.041	0.104	0.747	2.715	10.550	−1.02	11.58	2066		nm	
163	0.587	−0.050	0.170	0.597	2.722	11.220	−0.70	11.92	2418		nm	
73	0.405	−0.044	0.127	0.696	2.727	11.230	−0.71	11.94	2440		nm	
25	0.456	−0.106	0.083	0.101	2.592	8.560	−3.73	12.29	2873		nm	
55	0.453	−0.049	0.123	0.617	2.671	10.510	−1.85	12.35	2956		nm	
92	0.284	0.152	0.145	1.004	2.757	11.960	−0.41	12.37	2980		nm	
60	0.437	−0.041	0.157	0.740	2.687	11.040	−1.68	12.72	3492		nm	

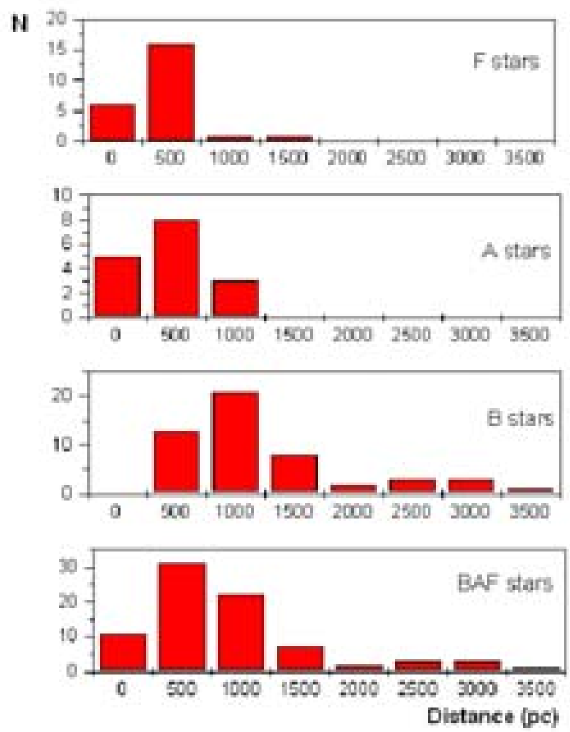

Fig. 3. Histograms of distance (pc) for the measured stars in the direction of NGC 6882/5.

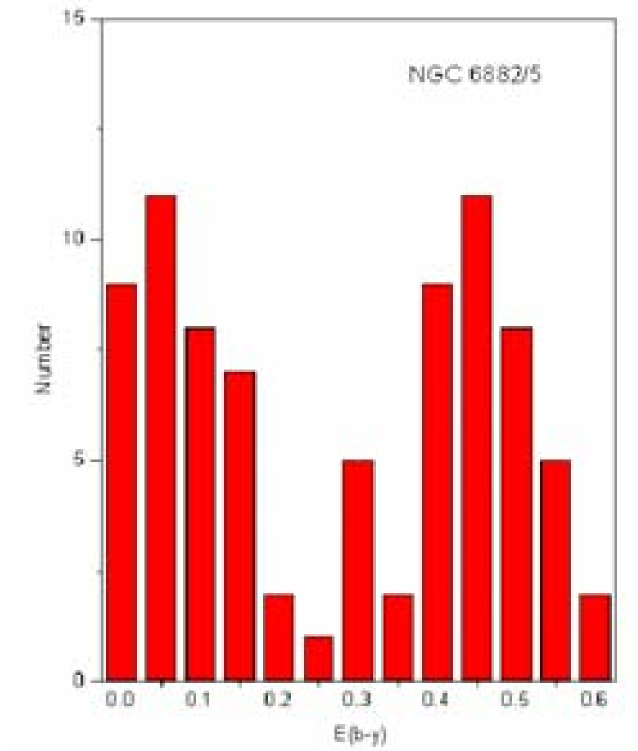

Fig. 4. Histogram of $E(b-y)$ for the measured stars in the direction of NGC 6882/5.

the F stars have their distance peak at 500 pc and a large spread towards the distances closer to the Sun. There is the same tendency in the A stars, with nearly equal numbers.

If a histogram of the reddening is constructed (Figure 4), two groups become evident: those stars with $E(b-y) < 0.25$ and those > 0.25. If a careful analysis of this results is considered, it is found that most of the stars in the first set, < 0.25, belong to the group of later-type stars which, by the way, is at a smaller distance, less than 500 pc, (Figure 5); the rest belong to early-type stars at greater distances. Two criteria can be employed to constitute the groups: distance and reddening.

The nearer cluster of stars, those centered at 500 pc, is mostly constituted of F and A stars with basically no early type stars. On the other hand, the more distant cluster, made up of mostly early type stars, does not show a clear accumulation of stars. If the bin size in the distance histogram is changed, for example to 500 pc, a column is clearly discernible but such dimension would be unreasonable for an open cluster. However, if this bin size is diminished to 200 pc, the distribution of the stars is spread out into three columns, in which the accumulation of the nearer group is still clear whereas the distribution of the farthest stars is spread out in an extended region in which two accumulations are discernible. This fact has to be interpreted as a region of star formation at distances from 600 pc up to 1300 pc from the Sun with accumulations at 700 and 1000 pc.

We will consider this distribution as final for the stars in the direction of NGC 6882, i.e., there are three different star accumulations. The Gaussian fits for each region give means at 303 ± 122 pc; 708 ± 68; and 1051 ± 234 pc, respectively. When these limits are assumed for the stars, the nearest cluster is constituted of 19 stars, at a mean distance of 289 ± 92 pc, and with a mean extinction $E(b-y)$ of 0.076 ± 0.085. Since it is constituted mainly of A and F stars, the metallicity [Fe/H]] was determined from the output of the F type stars and is 0.236 ± 0.295. The moderately distant cluster is constituted of only eight stars of the three spectral classes: B, A and F. Their mean distance is 695 ± 44 pc with a mean extinction $E(b-y)$ of 0.253 ± 0.154. Finally, the farthest cluster comprises twenty two stars at a mean distance of 1019 ± 134 pc with an extinction $E(b-y)$ of 0.379 ± 0.167 mag. It is basically constituted of B and A stars with only one F star with atypical

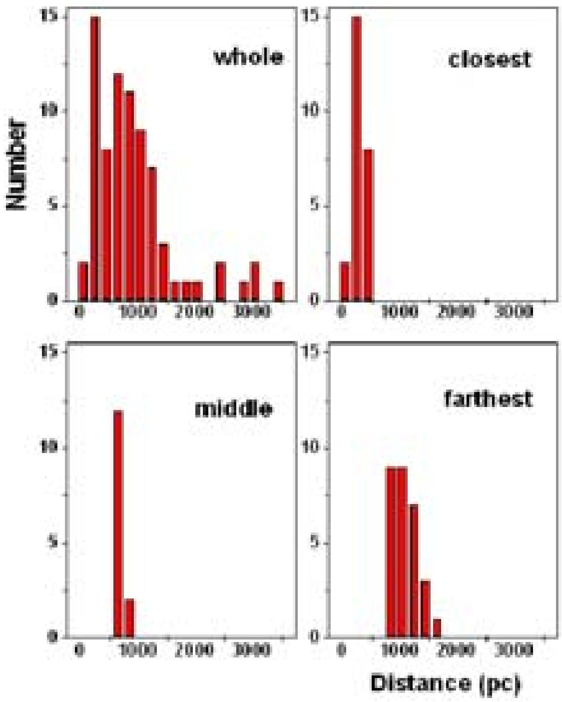

Fig. 5. Histograms of $E(b-y)$ and corresponding distances for a bin size of 500 pc. Top, histograms of the whole sample; middle histograms for the closest stars, bottom, for the farthest stars.

extinction (0.064 mag). The mean extinction for the rest of the sample if this F star is not considered, would be 0.394 ± 0.155 mag.

Once the three groups have been established, we might consider their ages. However, we must first establish which are the hottest stars for each group; then, from the numerical prescriptions of Meynet, Mermilliod, & Maeder (1993) we can determine the ages. Temperatures were determined by plotting the location of all stars on the theoretical grids of LGK86 once we had evaluated the unreddened colors (Figure 6). In all cases we utilized the $(b-y)$ vs c_0 diagrams which allow the determination of the temperatures with an accuracy of a few hundredths of degrees. The hottest stars, their temperatures, as well as the determined ages are listed in Table 5.

5. VALIDITY OF THE RESULTS

The crucial question of the existence of the clusters in the same direction, has been solved. However, in order to state this, the validity of the results should be unquestionable. As has been said in the previous sections, the high accuracy of each observed star in the three seasons was attained by multiply ob-

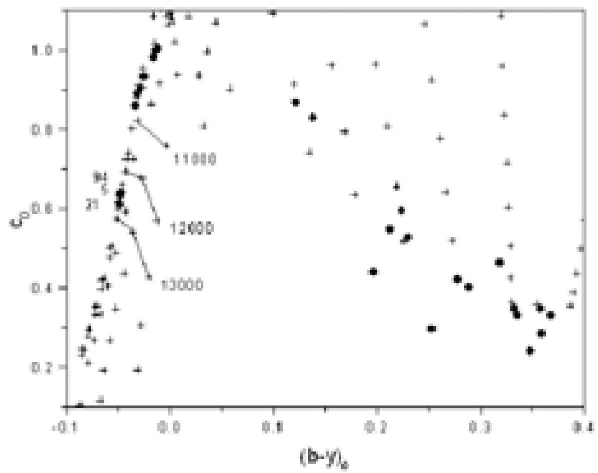

Fig. 6. Location of the stars of the farthest cluster in the grids of LGK86 for solar composition. The hottest stars have been indicated by their Webda numbers. The other numbers represent the temperature in K.

TABLE 5

DETERMINED AGES FOR EACH CLUSTER

Cluster	Star	T_e	$\log T_e$	log age
Closest	105	8000	3.903	8.855
	107	7800	3.896	8.907
Intermediate	39	13200	4.121	8.075
	94	13000	4.114	8.100
Farthest	43	13900	4.143	7.996
	41	13700	4.137	8.017

serving each star in sequences of five 10 sec integrations. Hence, mean values and standard deviations were calculated to determine the signal/noise ratio (Table 6). In all cases enough star counts were secured to attain a signal to noise ratio large enough to obtain an accuracy better than 0.01 mag. Nevertheless, it is obvious that brighter stars were more accurately observed than fainter ones; quoting Nissen (1988): "as expected from photon statistics considerations, the average mean errors increase as we go to fainter magnitudes". Unfortunately, since the aim of this project was to observe as many stars as possible, most of them were observed only twice, and a few, only once. The high dispersion in Hβ in the interval range 9–10 is due to one star, W216. Without it, the averaged dispersion turns out to be 0.094, high but a more reasonable figure. As has been said in previous sections, the uncertainties of the 1986 season were determined from the

TABLE 6

DETERMINATION OF THE ACCURACY OF OUR MEASUREMENTS FOLLOWING NISSEN (1988)

$V_{\rm int}$	N	$\langle\Delta V\rangle$	$\Delta\langle(b-y)\rangle$	$\langle\Delta m_1\rangle$	$\langle\Delta c_1\rangle$	$\langle\Delta\beta\rangle$	$N_{\rm rep}$
5-7	3	0.021	0.005	0.009	0.009	0.088	3
7-9	3	0.009	0.003	0.011	0.014	0.090	2
9-10	5	0.004	0.002	0.007	0.015	0.127	2
10-11	11	0.010	0.005	0.012	0.019	0.065	2
11-12	7	0.013	0.003	0.011	0.009	0.046	2
12-13	12	0.016	0.010	0.018	0.024	0.081	2
13-14	8	0.018	0.020	0.029	0.024	0.131	2

differences between the derived magnitude of the standard stars vs. the values reported in the literature. The average values of such differences are $\Delta(V, b-y, m_1, c_1) = (0.008, 0.005, -0.004, 0.012)$; on most nights at least ten standard stars were observed but this figure increased to 15 on some nights. The number of the whole sample of standard data points, due to the large time span of the season, was considerable, adding up to 80 points of standard stars.

Again following Nissen's (1988) work on the propagation of errors for the reddening (his § 3), the intrinsic color index $(b-y)_0$ has served to determine the individual color excess, $E(b{-}y) = (b{-}y){-}(b{-}y)_0$ and, as in his paper, assuming the photometric mean errors given for our observations, although larger than Nissen's (1988) work, we do expect a mean error $E(b{-}y)$ close to that derived by Nissen of 0.011 for F stars and of 0.009 for A stars since our errors are not exceedingly different. Nevertheless, no matter how large the observational errors, from the numbers we have handled no explanation could be given for the large differences found in Figure 4 in which two very distinct peaks at $E(b-y)$ of 0.05 and 0.45 mag are found. This could not be due to bias caused on the different calibration followed for early stars (Shobbrook 1984) or for intermediate type stars (Nissen 1988) because in an analogous study for the open cluster Alpha Perseus (Peña & Sareyan 2006) the same reddening and distance is determined for both types of stars for a sample of 178 measured stars.

With respect to the distance, Nissen (1988) in his section 3.3 finds that the corresponding mean error of DM_0 is ± 0.2 mag and later assigns membership for those stars with $|DM_0$- $\langle DM\rangle|$ of 0.6, i.e., three times the estimated mean error of DM_0. In a similar procedure we have established membership for those stars which are within one sigma of the mean of the histogram distribution of the whole sample. Those stars with a numerical values much larger than 0.02 mag, are supposed by Nissen to be probable binaries. However, as can be seen in our Figure 3, or its detailed presentation in Figure 5, the DM dispersion is too high to be explained merely by one cluster. Hence we have concluded the existence of at least two clusters on the same line of sight in a rich star forming region.

6. SHORT PERIOD VARIABLE STARS

As was mentioned in the Introduction, a search for short period variable stars was done in the past (Peña et al. 1990). Of the five observed stars two were found to be variables, as was reported in their Table 1, which is presented here in Table 7, along with the derived pulsational quantities. Later, Hintz et al. (2005) published a study devoted to these and some newly found short period variables. With new CCD photometry complemented with spectroscopy they concluded that one star, V382 Vul, which was assumed to be a δ Scuti star was instead a B3 star, a conclusion reached through spectroscopic results, which suggested since its periodicity was unquestionable, a β Cepheid star. The other star, V381 Vul was confirmed to be a δ Scuti star but a new period of 0.1185 d was proposed. Five new variables were found: two pulsators, and three eclipsing binary systems. With new $uvby-\beta$ photometry we will try to broaden the characteristics of those variables. Unfortunately, of the seven variables reported by H&R, three were not observed with $uvby-\beta$ photometry. A list of their unreddened photometry is presented in Table 8.

From the $uvby-\beta$ photometry of these stars one can immediately see that most of the observed stars monitored for detection of variability do belong to the nearer cluster (Table 4), say NGC 6882, and the

TABLE 7

PARAMETERS OF THE OBSERVED STARS IN THE SEARCH OF DETECTION OF SHORT PERIOD VARIABILITY

Id Webda	Id H&R	$V_{(H\&R)}$	$V_{(PP)}$	$b-y$	m_1	c_1	β	Sp	Type
19	1	10.257	12.902	0.0383	0.148	0.687	2.732	AF	V381Vul
	8	11.724							WUma
	13	11.484							delta
25	28	10.558	10.523	0.350	−0.054	0.188	2.592	BA	betaCep
126	47								eclipsing
18	72	10.229	12.902	0.383	0.148	0.687	2.732	AF	eclipsing
86	78	12.233	12.200	0.302	0.081	0.796	2.778	BA	Delta?

TABLE 8

UNREDDENED MAGNITUDES AND COLORS OF THE STARS MONITORED FOR VARIABILITY

ID Webda	ID Hintz & Rose	$E(b-y)$	$(b-y)_0$	m_0	c_0	β	V_0	M_v	DM mag	DST pc
19	1	0.126	0.138	0.220	0.829	2.801	9.68	2.11	7.57	327
25	28	0.456	−0.106	0.083	0.101	2.592	8.56	−3.73	12.29	2873
18	72									
86	78	0.344	−0.042	0.184	0.731	2.778	10.72	0.06	10.66	1354
09		0.012	0.153	0.208	0.718	2.799	9.21	3.29	5.92	153
19		0.126	0.138	0.220	0.829	2.801	9.68	2.11	7.57	327
5		0.042	−0.048	0.099	0.634	2.721	7.47	−0.75	8.22	441
08		0.000	0.310	0.152	0.392	2.641	9.20	3.76	5.44	122

remaining one, W25 does not belong to either of the clusters. Hence, from the location and the characteristics of the variable star, W19, one can infer that it is a δ Scuti type star. The location of each star is fixed on the $(b-y)_0$ vs. c_0 diagrams of LGK86; from them, the surface temperatures and gravities, $\log T_{\rm e}$ and $\log g$, are determined for each star. The chemical composition [Fe/H], can be determined for the F type stars.

With the advantage of Strömgren photometry and the analysis carried out for the observed stars, more light can be thrown onto the variables found by H&R. First, as was described, the spectral type to which they belong had to be determined. The photometric spectral types are listed in Table 3. We call attention to the fact that there is an excellent concordance between the spectral types determined photometrically and those determined spectroscopically by H&R. In particular, the fact that V382 Vul, which was proposed as a Delta Scuti star by Peña et al. (1990) from UBV photometry and that was determined to be a β Cepheid star by H&R, was classified as an early type star. This concordance has already been tested with remarkable results in the study of Alpha Per (Peña & Sareyan 2006). From the unreddened indexes determined (Table 8), we can extract the following for the variables:

W19 = V381 = H&R1. As stated before, it is a δ Scuti star. The period has been more accurately determined to be 0.1185 d. Its effective temperature and surface gravity have been determined by plotting its position in the theoretical grids of LGK86. The numerical values are presented in Table 8. With the determined distance of 327 pc it does belong to the nearest cluster.

W25 = V382 Vul = H&R28. Both the spectral classification and the $uvby-\beta$ photometry reclassified it to an earlier spectral type than previously assigned by Peña et al (1990) which make this a β Cepheid star. Its temperature has been fixed on the LGK diagram as 22500 K. It does not belong to any cluster because it is at distance of 2800 pc.

TABLE 9

PHYSICAL PARAMETERS OF THE VARIABLE STAR FOUND

ID	P (d)	$\log g$	M_v	BC	$M_{\rm bol}$	$T_{\rm e}$ K	$\log T_{\rm e}$	$\log Q$	Q	$(b-y)_0$	M_v- $8.46(b-y)$
119	0.056	3.5	2.11	−0.11	2.00	7600	3.881	−1.8748	0.013	0.138	1.818

W18 = H&R72. It shows a discordant value in the apparent magnitudes from the present paper and Webda (12.902 and 10.18, respectively). This rather peculiar behavior becomes clear through H&R determination of this star as a W UMa type star. However, the ΔV difference of more than 2 magnitudes is not a typical amplitude variation for a W UMa type star. We could not determine its distance with the photometry reported in this paper because we observed it only once without knowing which phase this eclipsing binary was in. In view of this, no membership to any cluster can be assigned.

W86 = H&R78. This new variable is assumed to be a possible δ Scuti star by H&R; they claim it might appear to be in the group at 540 pc. We have determined, instead, a distance of 1350 pc which openly contradicts this statement. In reality, it might not even belong to the farthest group, which is constituted of brighter earlier spectral stars. Equally, we have determined it to be an early spectral type which makes it difficult for it to belong to the δ Scuti type, but be consistent with the distance determination. We propose, in view of its short period variability, as well as its spectral type, that it might belong, as W25, to the β Cepheid type stars.

Temperatures and surface gravities were measured from the LGK86 grids. The numerical values are presented in Table 9.

The pulsation mode for the δ Scuti star W19 is determined from the well-known relation (Petersen & Jorgensen 1972; Breger et al. 1990) in which the main period for each variable star has been deduced in the present paper

$$\log Q = -6.454 + \log P + 0.5 \log g + 0.1 M_{\rm bol} + \log T_{\rm e} \quad (1)$$

From the unreddened indexes and derived distances, Table 4, plus the derived period, the physical quantities listed in Table 9 are obtained. As can be seen, W19 is pulsating in a high overtone ($\geq$ 3H), although more accuracy is needed in the period before any definite conclusion can be reached.

7. CONCLUSIONS

From the photometry carried out on an exceedingly large number of stars in the direction of NGC6882/5 it is found that there is one distinct clustering of stars at 300 pc, constituted mostly of A and F type stars with a few earlier type stars. At greater distances there seems to be a large number of early type stars spread in a vast region which, broadly, can be centered at 1000 pc. The analysis of the reddening of these stars corroborates this result. Of the two previously found short period variables, one does belong to the cluster and is, beyond any doubt a δ Scuti star.

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