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# $uvby-\beta$ PHOTOELECTRIC PHOTOMETRY OF THE OPEN CLUSTERS NGC 6811 AND NGC 6830[1]

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RESUMEN

A partir de la fotometría fotoeléctrica $uvby-\beta$ de los cúmulos abiertos NGC 6811 (75 estrellas) y NGC 6830 (19 estrellas) realizamos la determinación de distancias y, por ende, la pertenencia de las estrellas a cada cúmulo. Asimismo, se determinaron la edad y el enrojecimiento de cada uno. Dado que recientemente se han determinado estrellas variables para el primero, realizamos un estudio de dichas variables.

ABSTRACT

From $uvby-\beta$ photometry of the open clusters NGC 6811 (75 stars), and NGC 6830 (19 stars) we were able to determine membership of the stars to each cluster, and fix the age and reddening for each. Since several short period stars have recently been found, we have carried out a study of these variables.

*Key Words:* open clusters and associations: individual (NGC 6811, NGC 6830) — techniques: photometric



## 1. INTRODUCTION

The study of open clusters and their short period variable stars is fundamental in stellar evolution. Because the cluster members are formed in almost the same physical conditions, they share similar stellar properties, such as age and chemical composition. The assumption of common age, metallicity and distance imposes strong constraints when modeling an ensemble of short period pulsators belonging to open clusters (e.g., Fox Machado et al. 2001, 2006). Thus, observational studies involving variable stars in open clusters have attracted more and more attention (e.g., Fox Machado et al. 2002; Li et al. 2002, 2004).

A series of papers (see Peña & Peniche 1994; Peña et al. 1998, 2003; Peña, Fox Machado, & Garrido 2007) study the physical nature of the short period variable stars in open clusters by means of Strömgren photometry, since, once their membership to the cluster has been established, their physical quantities can be unambiguously derived. In particular, the determination of physical parameters of cluster member stars from $uvby-\beta$ photometry can be done through a comparison with theoretical models (Lester, Gray, & Kurucz 1986, hereinafter LGK86).

As a continuation of our study, we now present observations of the open clusters NGC 6811 and NGC 6830. Both clusters have no previous published $uvby-\beta$ data.

Very recently, Luo et al. (2009) carried out a search for variable stars in the direction of NGC 6811 with CCD photometry in the $B$, and $V$ bands. They detected a total of sixteen variable stars. Among these variables, twelve were catalogued as $\delta$ Scuti stars, while no variability type was assigned to the remaining stars. They claim that the twelve $\delta$ Scuti stars are all very likely members of the cluster, which makes this cluster an interesting target for asteroseismological studies. Moreover, NGC 6811 has been selected as a asteroseismic target of the Kepler space mission (Borucki et al. 1997). Therefore, deriving accurate physical parameters for the pulsating star members is very important.

For NGC 6811 Luo et al. (2009) estimated an age of $\log(t) = 8.76 \pm 0.009$ from theoretical isochrone fitting to the color magnitude diagram (CMD here-

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TABLE 1

LOG OF THE OBSERVING SEASONS

| Epoch | Cluster | Initial date year mo day | Final date year mo day | Observers |
|---|---|---|---|---|
| 2009 June | NGC 6811, NGC 6830 | 2009 06 24 | 2010 06 29 | jhp, hg, arl |
| 2010 August | NGC 6811 | 2010 08 03 | 2010 08 06 | jhp, ss, er, ae |

Observers: jhp, J. H. Peña; hg, H. García; arl, A. Rentería; ss, S. Skinner; er, E. Romero; ae, A. Espinosa.

after) and assuming a metallicity of $Z = 0.019$. They determined the distance modulus and color excess as $10.59 \pm 0.09$ and $0.12 \pm 0.05$, respectively.

To the best of our knowledge, no $\delta$ Scuti variable stars have been reported in NGC 6830 to date.

According to the compilation of data of open clusters in Paunzen & Mermilliod (2007, WEBDA), NGC 6811 has a distance [pc] of 1215; a reddening [mag] of 0.160; a distance modulus [mag] of 10.92; a log age 8.799 and no data on metallicity reported. NGC 6830 has the following: distance [pc] 1639; reddening [mag] 0.501; distance modulus [mag] 12.63; log age 7.572 with no determined metallicity.

## 2. OBSERVATIONS

These were all taken at the Observatorio Astronómico Nacional, Mexico in two different seasons, those of 2009 and 2010. The dates are listed in Table 1. The 1.5 m telescope to which a spectrophotometer was attached was utilized at all times. The first observing season was carried out over six nights from June–July 2009. The ID charts utilized were those of WEBDA. When the NGC 6811 data were reduced, there were several stars whose photometry showed large discrepancies with the literature. In view of this and due to the fact that several $\delta$ Scuti stars were recently discovered in this cluster (Luo et al. 2009), a second observing season was planned in 2010 to measure all of these stars in the $uvby-\beta$ system.

### 2.1. *Data acquisition*

The following procedure was utilized during all nights: each measurement consisted of 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 H$\beta$. Individual uncertainties were determined by calculating the standard deviations of the fluxes in each filter for each star. 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 sufficient photons to get a S/N ratio of accuracy of $N/\sqrt{(N)}$ of 0.01 mag in most cases. Each night a series of standard stars was also observed to transform the data into the standard system. The reduction procedure was done with the numerical packages NABAPHOT (Arellano-Ferro & Parrao 1988) which reduce the data into a standard system, although some data were also taken from the *Astronomical Almanac* (2006) for the standard bright stars. The chosen system was that defined by the standard values of Olsen (1983) and the transformation equations are those defined by Grönbech, Olsen, & Strömgren (1976) and by Crawford & Mander (1966). In these equations, the coefficients D, F, H and L are the slope coefficients for $(b-y)$, $m_1$, $c_1$ and $\beta$, respectively. The coefficients B, J and I are the color terms of $V$, $m_1$, and $c_1$. The averaged transformation coefficients of each season determined from the mean of all nights are listed in Table 2 along with their standard deviations. Errors of the season were evaluated by means of the standard stars observed. These uncertainties were calculated through the differences in magnitude and colors, for ($V$, $b-y$, $m_1$, $c_1$ and $\beta$) as (0.020, 0.017, 0.011, 0.031, 0.011) respectively, which provide a numerical evaluation of our uncertainties. Emphasis is made on the large range of the standard stars in the magnitude and color values: $V$:(5.4, 8.7); $(b-y)$:(0.02, 0.80); $m_1$:(0.09, 0.67); $c_1$:(0.06, 1.12) and $\beta$:(2.53, 2.89).

The transformation equations used in the work have the following forms in which 'inst' stands for instrumental values and 'std' for photometric values in the standard system:

$$
\begin{aligned}
V &= \mathrm{A} + \mathrm{B}\ (b-y)(\mathrm{inst}) + y\ (\mathrm{inst}), \\
(b-y)\ (\mathrm{std}) &= \mathrm{C} + \mathrm{D}\ (b-y)(\mathrm{inst}), \\
m_1(\mathrm{std}) &= \mathrm{E} + \mathrm{F}\ m_1(\mathrm{inst}) + \mathrm{J}\ (b-y)(\mathrm{inst}), \\
c_1(\mathrm{std}) &= \mathrm{G} + \mathrm{H}\ c_1(\mathrm{inst}) + \mathrm{I}\ (b-y)(\mathrm{inst}), \\
\beta\ (\mathrm{std}) &= \mathrm{K} + \mathrm{L}\ \beta\ (\mathrm{inst}).
\end{aligned}
$$

TABLE 2

TRANSFORMATION COEFFICIENTS OBTAINED FOR THE TWO OBSERVING SEASONS

| Season | B | D | F | J | H | I | L |
|---|---|---|---|---|---|---|---|
| 2009 | −0.005 | 0.975 | 1.002 | 0.037 | 1.008 | −0.067 | −1.397 |
| $\sigma$ | 0.051 | 0.032 | 0.045 | 0.033 | 0.049 | 0.067 | 0.031 |
| 2010 | 0.002 | 0.962 | 1.021 | 0.025 | 0.991 | −0.006 | −1.309 |
| $\sigma$ | 0.013 | 0.003 | 0.034 | 0.002 | 0.042 | 0.145 | 0.021 |



Table 3 lists the photometric values of the observed stars for the NGC 6811 cluster. In this table we list the following: Column 1, the ID number as in WEBDA, which follows Lindoff's nomenclature; Columns 2 to 6 the measured photometric values (N denotes the times each star was measured) the next five columns list the standard deviations from our photometry and the final columns, the spectral type for each star, determined from the $[m1]$ $[c1]$ diagram and from WEBDA and Becker (1947). The agreement between the spectral types deduced from the photometry with that reported by spectroscopic methods is interesting to note. Although there is consistency among the three values, there also is some disagreement among them. For example, W113 has spectroscopic types A4 and A8 from WEBDA and Becker (1947), respectively and there are some stars (W16 and W37) that are defined as early type stars from the spectroscopy and as later types from the photometry. Nevertheless, we note that, in general, the spectral types are coincident within the three mentioned sources. The remaining stars we classified do not have reported spectral classes. Table 4 lists in Column 1 the ID of WEBDA, Columns 2 to 6 the photometric values, Column 7 the spectral type derived from the photometry and Columns 8 and 9 the spectral types listed by WEBDA which are, respectively, Hoag & Applequist (1965) and Turner (1976).

### 2.2. *Comparison with other photometries*

Since no $uvby-\beta$ has been previously obtained for these clusters, a comparison of our values was made with the available $UBV$ photometry reported in WEBDA.

NGC 6811. We compared our 2009 season photometry with that reported by WEBDA. The intersection of both sets is constituted of seventy five stars, some of them (four) showing a large difference, greater than 0.5 mag in $V$. There were some others (six) with differences larger than 0.1 mag. In view of this we planned and carried out a second campaign in 2010. Table 3 reports the mean values of the two observing campaigns; N indicates the number of measurements for each star. Among the stars with large differences found in the 2009 season and WEBDA, five were measured in both observational campaigns showing small differences between them. Hence, with high probability, the discrepancies cannot be attributed to our measurements because (i) these stars were measured in two different seasons one year apart by different observers and (ii) the measured standard stars show reasonable values when compared to the standard literature values. Hence, the differences can be due to either a misidentification of the star by previous authors or a variable nature of these stars. Despite these differences, a linear fit between both sets yields the equation $V_{(\mathrm{pp})} = 0.82 + 0.97\, V_{(\mathrm{WEBDA})}$ with a correlation coefficient of 0.97 and a standard deviation of 0.25. The color relationship yields $(b-y) = 0.06 + 0.57\,(B-V)$ with a correlation coefficient of 0.92 and a standard deviation of 0.09.

NGC 6830. This cluster was compared with those $UBV$ values reported by WEBDA for a set constituted of only seven stars. The linear fit between both sets gave the equation $V_{(\mathrm{pp})} = 0.477 + 0.958 \times V_{(\mathrm{WEBDA})}$ with a correlation coefficient of 0.997 and a standard deviation of 0.080. The relationship in $B-V$ and $b-y$ gave $(b-y) = 0.117 + 0.573 \times (B-V)$ with a correlation coefficient of 0.922 and a standard deviation of 0.022.

## 3. METHODOLOGY

In order to determine the physical characteristics of the stars in each cluster this procedure was followed.

The evaluation of the reddening was done by first establishing, 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

TABLE 3

$uvby-\beta$ PHOTOELECTRIC PHOTOMETRY OF THE OPEN CLUSTER NGC 6811

| WBD | V | $(b-y)$ | $m_1$ | $c_1$ | bt | sV | sby | sm$_1$ | sc$_1$ | sbt | N | Spectral Type | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | Photometry | WBD |
| 4 | 12.681 | 0.259 | 0.127 | 0.861 | 2.706 | | | | | | 1 | A3V | A7 |
| 5 | 11.795 | 0.168 | 0.185 | 0.950 | 2.770 | 0.067 | 0.028 | 0.015 | 0.029 | 0.062 | 28 | A5V | A2 |
| 6 | 14.463 | 0.786 | 0.291 | 0.554 | 2.538 | 0.076 | 0.111 | 0.108 | 0.226 | 0.071 | 3 | >G | |
| 7 | 14.381 | 0.399 | 0.125 | 0.388 | 2.588 | 0.201 | 0.071 | 0.221 | 0.104 | 0.020 | 3 | F7V | |
| 8 | 14.110 | 0.356 | 0.142 | 0.498 | 2.630 | 0.150 | 0.053 | 0.153 | 0.115 | 0.055 | 3 | F7V | |
| 9 | 12.081 | 0.166 | 0.218 | 0.959 | 2.790 | 0.080 | 0.015 | 0.029 | 0.067 | 0.077 | 3 | Ap | A1 |
| 10 | 14.234 | 0.339 | 0.223 | 0.346 | 2.525 | 0.283 | 0.073 | 0.065 | 0.153 | 0.180 | 3 | G2V | |
| 12 | 14.363 | 0.455 | 0.148 | 0.387 | 2.540 | 0.098 | 0.067 | 0.057 | 0.142 | 0.094 | 3 | G0V | |
| 13 | 15.055 | 0.567 | 0.058 | 0.542 | 2.585 | 0.264 | 0.158 | 0.164 | 0.277 | 0.037 | 2 | F7V | |
| 14 | 13.672 | 0.765 | 0.399 | 0.174 | 2.510 | 0.182 | 0.029 | 0.041 | 0.022 | 0.040 | 2 | >G | |
| 16 | 12.196 | 0.235 | 0.165 | 0.927 | 2.781 | | | | | | 1 | A5V | A4 |
| 18 | 12.118 | 0.236 | 0.144 | 0.966 | 2.806 | | | | | | 1 | A5V | A4 |
| 22 | 13.034 | 0.522 | 0.267 | 0.230 | 2.529 | 0.019 | 0.018 | 0.005 | 0.023 | 0.039 | 2 | K0V | |
| 23 | 13.981 | 0.558 | 0.227 | 0.185 | 2.655 | | | | | | 1 | >G | |
| 24 | 11.245 | 0.613 | 0.327 | 0.318 | 2.564 | 0.044 | 0.020 | 0.012 | 0.052 | 0.019 | 2 | >G | G8 |
| 26 | 11.414 | 0.197 | 0.186 | 0.985 | 2.795 | | | | | | 1 | A5V | |
| 31 | 13.308 | 0.327 | 0.131 | 0.635 | 2.760 | | | | | | 1 | F5V | |
| 32 | 11.351 | 0.640 | 0.349 | 0.322 | 2.583 | | | | | | 1 | >G | G |
| 33 | 11.917 | 0.232 | 0.149 | 0.950 | 2.771 | | | | | | 1 | A5V | A2 |
| 34 | 11.623 | 0.204 | 0.204 | 0.956 | 2.829 | | | | | | 1 | A5p | B9 |
| 35 | 13.859 | 0.325 | 0.206 | 0.406 | 2.559 | 0.084 | 0.071 | 0.052 | 0.071 | 0.020 | 2 | G2V | |
| 36 | 13.221 | 0.283 | 0.180 | 0.561 | 2.614 | 0.065 | 0.062 | 0.049 | 0.009 | 0.052 | 2 | G0V | |
| 37 | 11.113 | 0.182 | 0.181 | 0.933 | 2.766 | 0.034 | 0.013 | 0.006 | 0.023 | 0.040 | 29 | A5V-F5Ib | |
| 38 | 13.206 | 0.662 | 0.382 | 0.330 | 2.535 | 0.052 | 0.079 | 0.013 | 0.066 | 0.128 | 2 | >G | |
| 39 | 11.528 | 0.212 | 0.157 | 0.961 | 2.728 | 0.069 | 0.020 | 0.012 | 0.042 | | 29 | A5V | A4 |
| 40 | 13.070 | 0.111 | 0.147 | 0.632 | 2.673 | 0.127 | 0.062 | 0.073 | 0.100 | 0.071 | 2 | A1V | |
| 41 | 12.014 | 0.148 | 0.195 | 0.956 | 2.741 | 0.100 | 0.035 | 0.017 | 0.037 | | 29 | A5V | |
| 42 | 12.568 | 0.190 | 0.184 | 0.829 | 2.698 | 0.172 | 0.055 | 0.028 | 0.049 | 0.059 | 29 | A8V | |
| 43 | 12.743 | 0.268 | 0.176 | 0.785 | 2.658 | 0.023 | 0.000 | 0.001 | 0.049 | 0.030 | 2 | A8V | |
| 44 | 12.046 | 0.169 | 0.182 | 0.935 | 2.757 | 0.082 | 0.033 | 0.016 | 0.032 | 0.029 | 29 | A5V | |
| 45 | 12.705 | 0.204 | 0.194 | 0.831 | 2.735 | 0.142 | 0.027 | 0.015 | 0.040 | 0.039 | 3 | A8V | A5 |
| 46 | 12.958 | 0.329 | 0.116 | 0.533 | 2.645 | 0.058 | 0.006 | 0.017 | 0.047 | 0.043 | 3 | F5V | |
| 47 | 13.649 | 0.383 | 0.099 | 0.389 | 2.613 | 0.136 | 0.020 | 0.046 | 0.065 | 0.083 | 3 | F5V | |
| 49 | 12.422 | 0.218 | 0.142 | 0.978 | 2.822 | | | | | | 1 | A0V | A5 |
| 51 | 13.418 | 0.269 | 0.139 | 0.592 | 2.590 | 0.076 | 0.094 | 0.115 | 0.125 | 0.035 | 2 | F5V | |
| 53 | 12.754 | 0.178 | 0.191 | 0.898 | 2.774 | 0.076 | 0.020 | 0.030 | 0.045 | 0.085 | 3 | A5V | |
| 54 | 12.356 | 0.266 | 0.136 | 0.757 | 2.713 | 0.027 | 0.025 | 0.029 | 0.027 | 0.078 | 3 | A8V | |
| 56 | 12.160 | 0.247 | 0.149 | 0.787 | 2.691 | 0.013 | 0.025 | 0.024 | 0.055 | 0.037 | 2 | A8V | |
| 57 | 14.039 | 0.439 | 0.161 | 0.357 | 2.670 | 0.149 | 0.196 | 0.161 | 0.114 | 0.073 | 4 | G0V | |
| 58 | 14.350 | 0.622 | 0.219 | 0.151 | 2.650 | 0.187 | 0.231 | 0.122 | 0.256 | 0.132 | 3 | K0V | |
| 62 | 12.846 | 0.224 | 0.163 | 0.728 | 2.714 | | | | | | 2 | A8V | |
| 63 | 15.234 | 0.979 | 0.846 | 0.714 | | 0.193 | 0.569 | 0.401 | 0.677 | 0.294 | 2 | >G | |
| 64 | 13.609 | 0.352 | 0.088 | 0.557 | 2.897 | 0.041 | 0.016 | 0.056 | 0.021 | 0.366 | 2 | F2V | |
| 65 | 14.450 | 0.460 | 0.199 | 0.217 | 2.510 | 0.087 | 0.164 | 0.106 | 0.057 | 0.103 | 2 | G2V | |
| 68 | 10.850 | 0.272 | 0.152 | 0.869 | 2.737 | | | | | | 1 | A8V | A2 |
| 70 | 10.925 | 0.298 | 0.139 | 0.876 | 2.713 | | | | | | 1 | A5V | A4 |
| 71 | 13.716 | 0.388 | 0.154 | 0.473 | 2.551 | | | | | | 1 | G0V | A2 |
| 73 | 9.851 | 0.992 | 0.830 | 0.166 | 2.551 | | | | | | 1 | >G | K5 |
| 74 | 12.322 | 0.415 | 0.171 | 0.305 | 2.568 | 0.078 | 0.007 | 0.003 | 0.028 | 0.008 | 2 | G0V | |
| 77 | 13.860 | 0.257 | 0.206 | 0.461 | 2.650 | 0.120 | 0.040 | 0.041 | 0.028 | 0.025 | 2 | G0V | |
| 78 | 13.664 | 0.270 | 0.167 | 0.567 | 2.676 | 0.070 | 0.023 | 0.011 | 0.040 | 0.037 | 2 | F7V | |
| 79 | 10.393 | 0.935 | 0.719 | 0.146 | 2.519 | | | | | | 1 | >G | |
| 82 | 13.025 | 0.705 | 0.341 | 0.333 | 2.546 | | | | | | 1 | >G | |
| 85 | 12.860 | 0.308 | 0.134 | 0.545 | 2.684 | | | | | | 1 | F5V | |
| 86 | 13.389 | 0.334 | 0.106 | 0.490 | 2.662 | | | | | | 1 | F2V | |
| 87 | 12.622 | 0.380 | 0.206 | 0.399 | 2.617 | | | | | | 1 | G2V | |
| 92 | 12.260 | 0.221 | 0.166 | 0.722 | 2.704 | | | | | | 1 | A8V | |
| 99 | 11.962 | 0.168 | 0.184 | 0.957 | 2.817 | 0.036 | 0.036 | 0.028 | 0.028 | 0.078 | 2 | A5V | B9 |
| 101 | 10.682 | 0.671 | 0.393 | 0.333 | 2.569 | | | | | | 1 | >G | |
| 102 | 12.882 | 0.586 | 0.221 | 0.287 | 2.562 | | | | | | 1 | K0V | |
| 105 | 12.419 | 0.230 | 0.241 | 0.850 | 2.802 | | | | | | 1 | Ap | A7 |
| 106 | 11.379 | 0.301 | 0.138 | 0.796 | 2.713 | | | | | | 1 | A8V | A3 |
| 107 | 12.726 | 0.419 | 0.123 | 0.414 | 2.640 | | | | | | 1 | F7V | |
| 112 | 12.825 | 0.372 | 0.146 | 0.412 | 2.663 | | | | | | 1 | F9V | |
| 113 | 11.471 | 0.233 | 0.144 | 0.990 | 2.767 | | | | | | 1 | A5V | A4 |
| 114 | 12.145 | 0.229 | 0.141 | 0.967 | 2.786 | 0.020 | 0.033 | 0.019 | 0.053 | 0.035 | 3 | A5V | B7 |
| 115 | 11.551 | 0.220 | 0.169 | 0.787 | 2.759 | 0.135 | 0.040 | 0.023 | 0.076 | 0.025 | 3 | A3V | A1 |
| 118 | 12.352 | 0.469 | 0.174 | 0.399 | 2.548 | | | | | | 1 | G2V | |
| 122 | 12.825 | 0.372 | 0.146 | 0.412 | 2.663 | | | | | | 1 | F9V | |
| 123 | 13.970 | 0.648 | 0.689 | 0.386 | 2.579 | | | | | | 1 | >G | |
| 133 | 12.069 | 0.576 | 0.346 | 0.230 | 2.510 | | | | | | 1 | >G | G2 |
| 139 | 13.197 | 0.358 | 0.082 | 0.569 | 2.646 | | | | | | 1 | F2V | |
| 146 | 12.504 | 0.353 | 0.151 | 0.475 | 2.650 | | | | | | 1 | F9V | |
| 147 | 12.129 | 0.168 | 0.200 | 0.972 | 2.847 | | | | | | 1 | A5V | A4 |
| 178 | 9.909 | 1.039 | 0.839 | 0.225 | 2.835 | | | | | | 1 | >G | |
| 218 | 12.087 | 0.194 | 0.157 | 0.982 | 2.858 | | | | | | 1 | A5V | A5 |
| 489 | 11.000 | 0.252 | 0.179 | 0.855 | 2.748 | | | | | | 1 | A5V | |
| 491 | 13.681 | 0.240 | 0.241 | 0.857 | 2.889 | | | | | | 1 | Ap | |
| V17 | 15.009 | 0.560 | 0.067 | 0.157 | 2.468 | | | | | | 1 | F9V | |

TABLE 4

$uvby-\beta$ PHOTOELECTRIC PHOTOMETRY OF THE OPEN CLUSTER NGC 6830

| ID | $V$ | $(b-y)$ | $m_1$ | $c_1$ | $\beta$ | SpTyp | | sptp |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Phe | Spc | |
| 5 | 9.849 | 0.266 | 0.013 | 0.554 | 2.721 | B6V | B7 V | B5 III |
| 7 | 11.176 | 0.353 | 0.007 | 0.822 | 2.689 | B8V | A0 V | B7 III |
| 8 | 11.540 | 0.373 | −0.018 | 0.716 | 2.616 | B7V | B7 IV | |
| 49 | 10.956 | 0.456 | 0.103 | 0.875 | 2.751 | AV5 | | |
| 4 | 12.623 | 0.600 | −0.100 | 0.471 | 2.685 | B3V | | |
| 2258 | 13.003 | 0.546 | 0.086 | 0.484 | 2.721 | F9V | | |
| 2257 | 12.166 | 0.390 | −0.008 | 0.584 | 2.706 | B7V | | |
| 26 | 12.309 | 0.564 | 0.160 | 0.255 | 2.661 | G1V | | |
| 164 | 12.240 | 0.460 | 0.093 | 0.819 | 2.766 | A8V | | |
| 25 | 12.465 | 0.333 | 0.012 | 0.661 | 2.718 | B8V | | |
| 24 | 11.644 | 0.391 | −0.034 | 0.612 | 2.635 | B5V | B6 V | B6 IV |
| 2 | 10.625 | 0.329 | −0.017 | 0.606 | 2.603 | B5V | | |
| 3 | 12.888 | 1.620 | 0.383 | 0.256 | 2.569 | K G | | |
| 39 | 11.192 | 0.386 | −0.051 | 0.681 | 2.668 | B8I | B5 IV | |
| 2275 | 11.909 | 1.160 | 0.306 | −0.047 | 2.576 | B7V | | |
| 13 | 12.787 | 0.767 | 0.134 | 0.380 | 2.605 | K0V | | |
| 14 | 11.995 | 0.348 | 0.017 | 0.532 | 2.714 | B6V | B6 V | B6 IV |
| 15 | 12.659 | 0.407 | −0.035 | 0.646 | 2.681 | B6V | | |
| 16 | 12.456 | 0.408 | 0.108 | 0.807 | 2.794 | K | | |



(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, the location of the stars in the $[m_1]-[c_1]$ diagram was employed as a primary criteron. In Tables 3 and 4 the photometrically determined spectral class has been indicated. The determined spectral types compiled in the literature are also presented.

The reddening determination was obtained from the spectral types through Strömgren photometry. The application of the calibrations developed for each spectral type (Shobbrook 1984 for O and early A types and Nissen 1988 for late A and F stars) were considered. No determination of reddening was calculated for G and later spectral types. The results of applying such calibrations are shown in Tables 5 and 6 for NGC 6811 and NGC 6830, respectively. In Table 5, the following columns are presented: Column 1 the ID (WEBDA) for each star; Column 2, the reddening $E(b-y)$; Columns 3 to 5, the unreddened indexes $(b-y)_0$, $m_0$, and $c_0$; Column 6 the H$\beta$ value; Columns 7 and 8 $V_0$, and the absolute magnitude, respectively. Columns 9 and 10 show the distance modulus and the distance in parsecs. The metallicity is presented in Column 11 and, finally, Column 12 lists the membership to the cluster, denoted by M (member) or NM (non-member). The membership was determined from the distance modulus or distance histograms. A Gaussian fit with a bin size of one was done to the bars in the histogram to all the stars and the obtained fit is presented, along with the uncertainties in each figure. Membership then was established from the above mentioned fit. Stars within a standard deviation value from the mean were considered to be members. Those with standard deviation values slightly larger than one sigma are considered to be stars with marginal membership. In the table, those stars that are considered to be members of the cluster are denoted by an ‘m’. Marginal membership is indicated by a semi-colon, ‘m:’, those that were non-members are denoted by ‘nm’. Table 6 is analogous. Probable members are denoted by a semicolon.

TABLE 5

REDDENING, UNREDDENED PARAMETERS AND DISTANCE FOR THE OPEN CLUSTER NGC 6811

| ID | $E(b-y)$ | $(b-y)_0$ | $m_0$ | $c_0$ | $\beta$ | $V_0$ | $M_V$ | DM | DST | [Fe/H] | Memb |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 112 | 0.082 | 0.290 | 0.171 | 0.396 | 2.663 | 12.47 | 3.82 | 8.7 | 537 | 0.1 | NM |
| 122 | 0.082 | 0.290 | 0.171 | 0.396 | 2.663 | 12.47 | 3.82 | 8.7 | 537 | 0.1 | NM |
| 107 | 0.108 | 0.311 | 0.155 | 0.392 | 2.640 | 12.26 | 3.47 | 8.8 | 574 | −0.2 | NM |
| 31 | 0.134 | 0.193 | 0.171 | 0.608 | 2.760 | 12.73 | 3.47 | 9.3 | 713 | | M |
| 489 | 0.072 | 0.180 | 0.201 | 0.841 | 2.748 | 10.69 | 1.32 | 9.4 | 749 | | M |
| 146 | 0.052 | 0.301 | 0.167 | 0.465 | 2.650 | 12.28 | 2.82 | 9.5 | 780 | 0.0 | M |
| 68 | 0.085 | 0.187 | 0.177 | 0.852 | 2.737 | 10.48 | 1.01 | 9.5 | 786 | | M |
| 34 | 0.099 | 0.105 | 0.234 | 0.936 | 2.829 | 11.20 | 1.57 | 9.6 | 842 | | M |
| 105 | 0.093 | 0.137 | 0.269 | 0.831 | 2.802 | 12.02 | 2.16 | 9.9 | 938 | | M |
| 85 | 0.055 | 0.253 | 0.150 | 0.534 | 2.684 | 12.63 | 2.71 | 9.9 | 964 | −0.1 | M |
| 218 | 0.116 | 0.078 | 0.192 | 0.959 | 2.858 | 11.59 | 1.65 | 9.9 | 973 | | M |
| 106 | 0.088 | 0.213 | 0.164 | 0.778 | 2.713 | 11.00 | 1.06 | 9.9 | 973 | 0.0 | M |
| 47 | 0.060 | 0.323 | 0.117 | 0.377 | 2.613 | 13.39 | 3.42 | 10.0 | 985 | −0.7 | M |
| 37 | 0.024 | 0.158 | 0.188 | 0.928 | 2.766 | 11.01 | 0.87 | 10.1 | 1065 | | M |
| 147 | 0.080 | 0.088 | 0.224 | 0.956 | 2.847 | 11.79 | 1.62 | 10.2 | 1080 | | M |
| 70 | 0.089 | 0.209 | 0.166 | 0.858 | 2.713 | 10.54 | 0.31 | 10.2 | 1112 | 0.0 | M |
| 86 | 0.061 | 0.273 | 0.124 | 0.478 | 2.662 | 13.13 | 2.88 | 10.3 | 1120 | −0.5 | M |
| 26 | 0.067 | 0.130 | 0.206 | 0.972 | 2.795 | 11.12 | 0.84 | 10.3 | 1140 | | M |
| 99 | 0.053 | 0.115 | 0.200 | 0.946 | 2.817 | 11.73 | 1.42 | 10.3 | 1154 | | M |
| 18 | 0.113 | 0.123 | 0.178 | 0.943 | 2.806 | 11.63 | 1.18 | 10.5 | 1233 | | M |
| 115B | 0.261 | −0.041 | 0.247 | 0.737 | 2.759 | 10.43 | −0.22 | 10.6 | 1345 | | M |
| 16 | 0.088 | 0.147 | 0.192 | 0.909 | 2.781 | 11.82 | 1.15 | 10.7 | 1357 | | M |
| 54 | 0.052 | 0.214 | 0.152 | 0.747 | 2.713 | 12.13 | 1.43 | 10.7 | 1384 | −0.2 | M |
| 113 | 0.082 | 0.151 | 0.168 | 0.974 | 2.767 | 11.12 | 0.37 | 10.8 | 1409 | | M |
| 92 | 0.000 | 0.226 | 0.166 | 0.722 | 2.704 | 12.26 | 1.49 | 10.8 | 1423 | 0.0 | M |
| 46 | 0.040 | 0.289 | 0.128 | 0.525 | 2.645 | 12.79 | 2.01 | 10.8 | 1431 | −0.5 | M |
| 33 | 0.080 | 0.152 | 0.173 | 0.934 | 2.771 | 11.57 | 0.79 | 10.8 | 1431 | | M |
| 114 | 0.090 | 0.139 | 0.168 | 0.949 | 2.786 | 11.76 | 0.87 | 10.9 | 1506 | | M |
| 049B | 0.244 | −0.026 | 0.215 | 0.932 | 2.822 | 11.37 | 0.48 | 10.9 | 1513 | | M |
| 5 | 0.015 | 0.153 | 0.189 | 0.947 | 2.770 | 11.73 | 0.78 | 11.0 | 1549 | | M |
| 9 | 0.030 | 0.136 | 0.227 | 0.953 | 2.790 | 11.95 | 1.00 | 11.0 | 1551 | | M |
| 62 | 0.008 | 0.216 | 0.165 | 0.726 | 2.714 | 12.81 | 1.72 | 11.1 | 1650 | 0.0 | M |
| 139 | 0.080 | 0.278 | 0.106 | 0.553 | 2.646 | 12.85 | 1.57 | 11.3 | 1808 | −0.7 | M |
| 44 | 0.004 | 0.165 | 0.183 | 0.934 | 2.757 | 12.03 | 0.72 | 11.3 | 1824 | | M |
| 53 | 0.023 | 0.155 | 0.198 | 0.893 | 2.774 | 12.66 | 1.31 | 11.4 | 1860 | | M |
| 45 | 0.012 | 0.192 | 0.198 | 0.829 | 2.735 | 12.65 | 1.30 | 11.4 | 1863 | | M |
| 78 | 0.004 | 0.266 | 0.168 | 0.566 | 2.676 | 13.65 | 2.27 | 11.4 | 1882 | 0.1 | M: |
| 39 | 0.028 | 0.184 | 0.165 | 0.955 | 2.728 | 11.41 | −0.03 | 11.4 | 1938 | | NM |
| 41 | 0.000 | 0.176 | 0.195 | 0.956 | 2.741 | 12.01 | 0.31 | 11.7 | 2192 | | NM |
| 8 | 0.039 | 0.317 | 0.154 | 0.490 | 2.630 | 13.94 | 2.20 | 11.7 | 2230 | −0.3 | NM |
| 56 | 0.013 | 0.234 | 0.153 | 0.784 | 2.691 | 12.11 | 0.36 | 11.8 | 2238 | −0.1 | NM |
| 36 | 0.000 | 0.344 | 0.180 | 0.561 | 2.614 | 13.22 | 0.98 | 12.2 | 2805 | −0.1 | NM |
| 42 | 0.000 | 0.231 | 0.184 | 0.829 | 2.698 | 12.57 | 0.22 | 12.4 | 2952 | 0.3 | NM |
| 004B | 0.296 | −0.037 | 0.216 | 0.805 | 2.706 | 11.41 | −1.33 | 12.7 | 3532 | | NM |
| 51 | 0.000 | 0.342 | 0.139 | 0.592 | 2.590 | 13.42 | −0.09 | 13.5 | 5033 | −0.6 | NM |
| 43 | 0.000 | 0.279 | 0.176 | 0.785 | 2.658 | 12.74 | −0.77 | 13.5 | 5041 | 0.1 | NM |
| 040B | 0.161 | −0.050 | 0.195 | 0.601 | 2.673 | 12.38 | −1.76 | 14.1 | 6728 | | NM |
| Mean value | 0.074 | | | | | | | 10.42 | 1258 | −0.3 | |
| $\sigma$ | 0.057 | | | | | | | 0.61 | 339 | 0.3 | |

TABLE 6

REDDENING, UNREDDENED PARAMETERS AND DISTANCE FOR THE OPEN CLUSTER NGC 6830

| ID | $E(b-y)$ | $(b-y)_0$ | $m_0$ | $c_0$ | $\beta$ | $V_0$ | $M_V$ | DM | DST | [Fe/H] | Mbr |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 26 | 0.244 | 0.320 | 0.233 | 0.206 | 2.661 | 11.26 | 5.67 | 5.59 | 131 | 0.85 | nm |
| 2258 | 0.310 | 0.236 | 0.179 | 0.422 | 2.721 | 11.67 | 4.10 | 7.57 | 327 | | nm |
| 13 | 0.371 | 0.396 | 0.245 | 0.306 | 2.605 | 11.19 | 3.43 | 7.76 | 357 | 0.46 | nm |
| 164 | 0.291 | 0.169 | 0.180 | 0.761 | 2.766 | 10.99 | 1.90 | 9.09 | 658 | | nm |
| 5 | 0.326 | −0.060 | 0.111 | 0.492 | 2.721 | 8.45 | −0.65 | 9.10 | 661 | | m: |
| 4 | 0.677 | −0.077 | 0.103 | 0.342 | 2.685 | 9.71 | −1.25 | 10.96 | 1559 | | m |
| 14 | 0.412 | −0.064 | 0.141 | 0.454 | 2.714 | 10.22 | −0.76 | 10.98 | 1571 | | m |
| 7 | 0.394 | −0.041 | 0.125 | 0.747 | 2.689 | 9.48 | −1.64 | 11.12 | 1676 | | m |
| 2257 | 0.449 | −0.059 | 0.127 | 0.499 | 2.706 | 10.23 | −0.91 | 11.14 | 1692 | | m |
| 39 | 0.436 | −0.050 | 0.080 | 0.598 | 2.668 | 9.32 | −1.89 | 11.21 | 1745 | | m |
| 25 | 0.384 | −0.051 | 0.127 | 0.588 | 2.718 | 10.81 | −0.76 | 11.57 | 2063 | | m |
| 15 | 0.461 | −0.054 | 0.103 | 0.558 | 2.681 | 10.68 | −1.49 | 12.16 | 2709 | | m |
| 24 | 0.447 | −0.056 | 0.100 | 0.527 | 2.635 | 9.72 | −2.81 | 12.53 | 3200 | | m |
| 2 | 0.385 | −0.056 | 0.098 | 0.533 | 2.603 | 8.97 | −4.40 | 13.37 | 4719 | | nm |
| 8 | 0.420 | −0.047 | 0.108 | 0.636 | 2.616 | 9.73 | −4.08 | 13.81 | 5785 | | nm |

## 4. ANALYSIS

In order to gain some insight into the clusters we must first find out which stars belong to each one. As was already mentioned, this is accomplished by constructing a histogram of the deduced distances. From the results listed in Tables 5 and 6 and shown in Figure 1, we can establish that NGC 6811 has a distinctive accumulation of thirty-seven stars at a distance modulus of $10.5 \pm 1.0$ mag, whereas NGC 6830 is merely an association of eight early type stars at DM $11.1 \pm 1.6$ mag, although emphasis should be made on the fact that we merely observed a small sample of stars in the direction of this cluster: nineteen of the brightest stars. According to the study of Netopil et al. (2007) four CP stars in NGC 6830 were found. Since Strömgren photometry is most suitable for this topic, we checked our measured stars for the Ap determination. Unfortunately, none of our measured stars lay in the regions defined by the boxes in the $m_0$, and $c_0$ diagram where the Ap stars should be, as in Golay's (1974, Figure 124). Hence, we cannot corroborate, nor discard the findings by Netopil et al. (2007). For NGC 6811 we determined four stars belonging to the Ap category, namely W9, W34, W105 and W491, all to the Sr-Cr-Eu class.

Age is fixed for the two determined clusters once we measured the hottest and hence the brightest stars for each one. The effective temperature of these hottest stars was determined by plotting the location of all stars on the theoretical grids of LGK86, once we evaluated the unreddened colors (Figure 2) for a solar chemical composition. We considered this metallicity based on the thirteen F type stars for which we determined the metallicity [Fe/H]; a mean value of $-0.18 \pm 0.30$ was found. In the related figures, LGK86 in the upper left corner indicates that the grids were taken from the mentioned reference of LGK86 and the specified metalicity. We have utilized the $(b-y)$ vs. $c_0$ diagrams which allow the determination of the temperatures with an accuracy of a few hundreds of degrees. However, for NGC 6811, as can be seen in Figure 2, the stars are clustered together and the effective temperature cannot be easily determined. To measure the temperature with more accuracy, a plot of $(b-y)$ vs. $\beta$ was constructed and compared with the theoretical grids of LGK86, Figure 3. The temperature for the hottest stars is around 11,700 K for NGC 6811, whereas for NGC 6830 it is much hotter (17,000 K). Once membership has been established, age is determined after calculating the effective temperature through the calibrations of Meynet, Mermilliod, & Maeder (1993) for open clusters; a log age of 8.266 ($1.845 \times 10^8$ yr) is found from the relation $-3.611 \log\log T_{\rm eff} + 22.956$ valid in the range $\log\log T_{\rm eff}$ within the limits [3.98, 4.25] for NGC 6811; whereas for NGC 6830 the re-

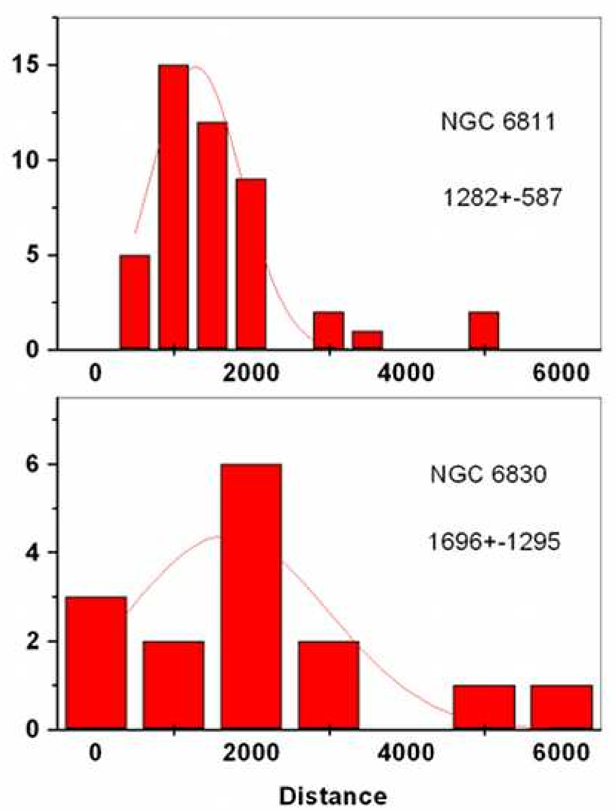


Fig. 1. Histogram of the distance modulus ($X$ axis, in magnitudes) found for the B, A and F stars in the direction of NGC 6811 (top) and NGC 6830 (bottom).

lation $\log(\mathrm{age}) = -3.499 \log\log T_{\mathrm{eff}} + 22.476$ valid in the range [4.25, 4.56] yields log(age) of 7.69 ($4.89 \times 10^7$ yr).

These determinations are confirmed by constructing the color-magnitude diagram of NGC 6811 and NGC 6830 which are shown in Figures 4 and 5, respectively. The unreddened magnitudes $[(b-y)_0,\ M_V]$ of cluster members taken from Tables 5 (NGC 6811) and 6 (NGC 6830) are shown with filled circles. In each plot two theoretical isochrones in the Strömgren photometric system are shown with solid and dashed lines. The metallicity and ages are indicated in the figures. The theoretical isochrones were obtained from the Padova database (Girardi et al. 2003). As can be seen, the isochrones match the observed color-magnitude diagram with the ages and distance derived in the present paper.

## 5. VARIABLE STARS IN NGC 6811

As was stated in the introduction, Luo et al. (2009) performed time-series photometric observations of the open cluster NGC 6811 to search for variable stars. These observations were carried out

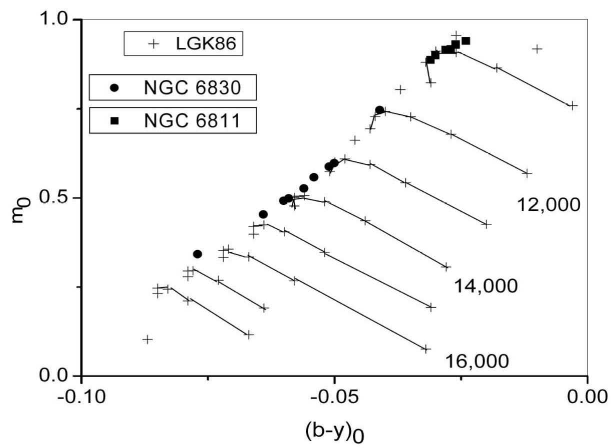


Fig. 2. Location of the unreddened points of the two clusters on the LGK86 grids. Squares: NGC 6811; dots: NGC 6830.

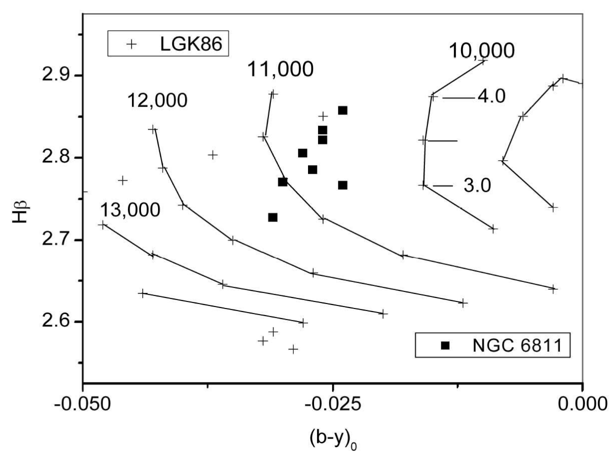


Fig. 3. Location of the unreddened points of the hot stars in the NGC 6811 cluster on the LGK86 grids.

during five nights from June 6 to July 24, 2008 utilizing the 85 cm telescope of the Xonglong Station of the National Astronomical Observatories of the Chinese Academy of Sciences. The instrumentation they used was a $1024 \times 1024$ CCD camera with a field of view of $16.5' \times 16.5'$ with standard Johnson-Cousin-Bessell filters in $B$ and $V$ bands, with which they obtained 750 CCD frames in each band. Sixteen certain variable stars were detected or confirmed from that survey, namely V1–V7 and V10–V18 following the variable name list of van Cauteren et al. (2005) (see Table 1 by Luo et al. 2009). Among these, twelve stars were catalogued as Delta Scuti variables based upon the light curves (V1–V7 and V10–V14). The omitted variables, V8 and V9, were outside of their

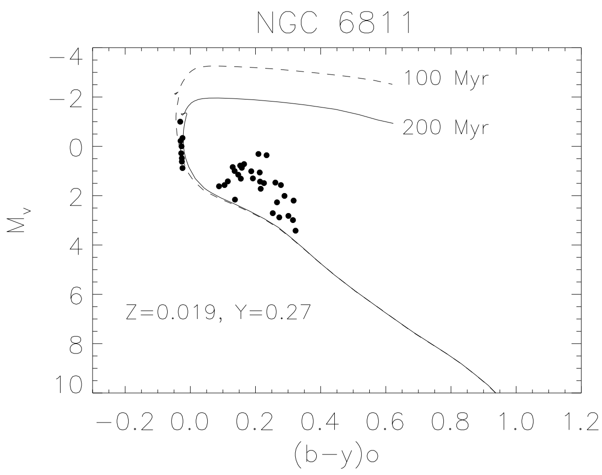


Fig. 4. Color-magnitude diagram of the NGC 6811 cluster considering only the cluster members. The target stars are represented by filled circles. Theoretical isochrones for 100 Myr (dashed line) and 200 Myr (solid line) computed with $Z = 0.019$ are shown.

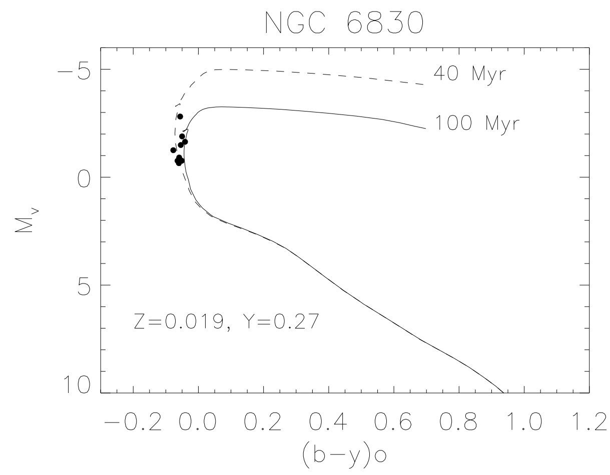


Fig. 5. Color-magnitude diagram of the NGC 6830 cluster considering only the cluster members. The target stars are represented by filled circles. Theoretical isochrones for 40 Myr (dashed line) and 100 Myr (solid line) computed with $Z = 0.019$ are shown.



field-of-view. In particular, Luo et al. (2009) discovered variability in V10–V18; four of them (V10, V12, V15, V16) had been just reported as suspected variables by Rose & Hintz (2007), while the variability of V1–V7 was discovered by van Cauteren et al. (2005). On the other hand, nine stars reported as variables by Rose & Hintz (2007) were not confirmed by Luo et al. (2009). One explanation provided for this inconsistency was that the amplitude of light variations was too low to be detected. Luo et al. 2009 also determined the membership probabilities of twelve variables (V1–V5 and V10–V16) through the proper-motion membership probabilities (PMP) listed by Sanders (1971). From these values they claim that with high probability all of the twelve stars (V1–V3, V5, V10–V16) are cluster members, except for V4. For the the stars without PMP data, namely V6, V7, V17 and V18, based on their position in the CMD diagram, they concluded that the first two are most likely members of the cluster whereas the last two are probably field stars.

On the night of August 6, 2010 (UT) we carried out a very short span of observations in differential photometric mode. The variables we considered were chosen due to their nearness and were, in the notation of Luo et al. (2009): V2, V4, V11 and V14 with W5 and W99 as reference and check stars. Although the time span we observed was too short to detect long period variation, the only star which showed a clear variation was V4, with two clearly discernible peaks of relatively large amplitude of variation, 0.188 mag, and a period of 0.025 d.

From our cluster membership determinations on a star-to-star basis, the conclusion we reach is slightly different from the previous assertions regarding variability. Memberships are determined for V1, V3, V4, V5, V10, V11, V13 and V16. Marginal membership for V12 and V14, non-membership for V15 and we were unable to determine membership for the remaining stars mainly because they do not belong to the spectral classes B, A or F but belong to a latter spectral type which makes them unlikely to be $\delta$ Scuti type variables. From the location of these variables in the theoretical grids of LGK86, Figures 6 and 7, we determine their temperatures.

## 6. CONFIDENCE OF THE RESULTS

As has been said in previous sections, the high accuracy of each observed star was attained by multiply observing each star in sequences of five 10 sec integrations. Hence, mean values and standard deviations were calculated to determine the signal/noise ratio. In all cases, enough star counts were secured to attain a signal to noise ratio large enough to achieve an accuracy better than 0.01 mag. Nevertheless, it is obvious that the brighter stars were more accurately observed than the 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 uncertainties of the season were determined from the differences between

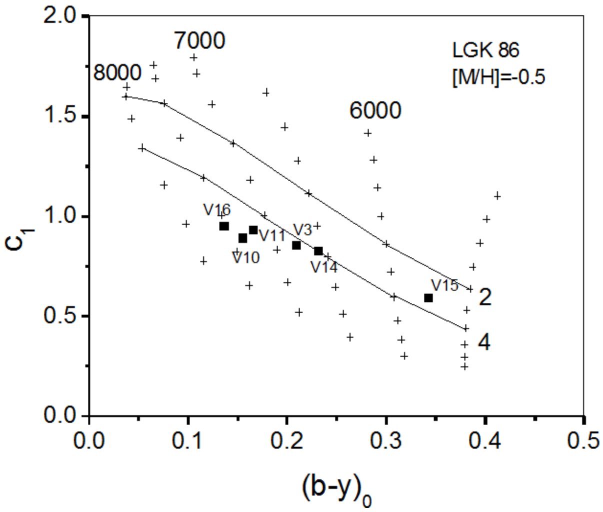


Fig. 6. Location of the $\delta$ Scuti stars of NGC 6811 on the theoretical grids of LGK86.

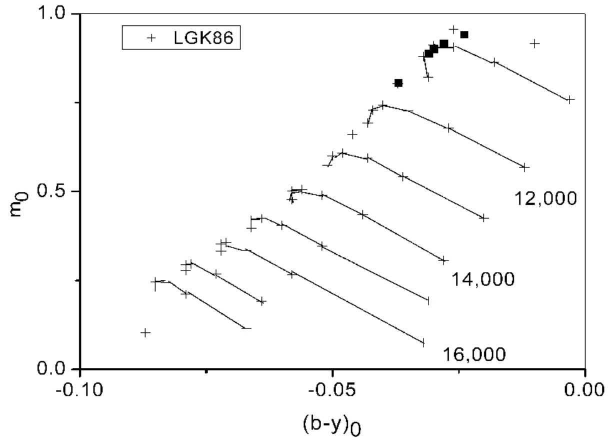


Fig. 7. Location of the hot variable stars of NGC 6811 on the theoretical grids of LGK86.

the derived magnitude of the standard stars vs. reported values in the literature. The average values of such differences are $\Delta(V,\ b-y,\ m_1,\ c_1) = (0.008,\ 0.005,\ -0.004,\ 0.012)$; 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 standards data points, due to the large time span of the season, was considerable, adding up to 80 points of standard stars.

To calculate the propagation of errors for the reddening (in Nissen's 1988 work, § 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 the work by Nissen (1988), 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.

## 7. DISCUSSION

New $uvby-\beta$ photoelectric photometry has been acquired and is presented for the brightest stars in the direction of two open clusters NGC 6811 and NGC 6830. From the observed stars in the field, some were determined to be early type stars, either B or A. Using the calibrations to determine reddening and distance for these stars, distances for the clusters have been obtained. Unreddened indexes in the LGK86 grids allowed us to determine the effective temperature of the hottest stars and hence, the age of the cluster.

A brief discussion of each cluster is presented. Table 7 lists the previous knowledge and the newly determined characteristics of the clusters.

NGC 6811. Considering the classical $UBV$ photometry compiled for this cluster, very little can be deduced about its properties. No clear distinction in the color-color diagram $B-V$ vs $U-B$ can be drawn; the same conclusion is reached from its HR diagram. From our results we have determined that 37 stars belong to the cluster. Since they are the brightest, the conclusion on the age, which agree with that previously determined, is also correct. We have found that the cluster is farther, its extinction is less and it is younger than previously assumed. The goodness of our method has been previously tested, as in the case of the open cluster Alpha Per (Peña & Sareyan 2006) against several sources which consider proper motion studies as well as results from the Hipparcos and Tycho data bases. Hence, we feel that our results throw new light regarding membership to this cluster.

There have been several previous works in which membership probabilities were considered. Table 8 lists the identification numbers from several studies, namely those of WEBDA, Luo et al. (2009), Sanders (1971), Becker (1947), Barkhatova, Zakharova, & Shashkina (1978) and more recently, the compilation by Kharchenko et al. (2005). We have repeated part of the information on the distance provided in Table 8 in order to support the conclusions based on the last columns of the table, which present the membership probability obtained in the present paper (PP), that of Sanders (1971) and those reported by the compilation of Kharchenko et al. (2005) based on

TABLE 7

COMPILED CHARACTERISTICS FOR NGC 6830 AND NGC 6811

| Cluster | Source | log age | Reddening $E(B-V)$ [mag] | Distance [kpc] | Metallicity |
|---|---|---|---|---|---|
| NGC 6830 | Barkhatova (1957) | – | – | 1.68 | – |
| | Hoag & Applequist (1965) | – | 0.51 | 1.38 | – |
| | Becker & Fenkart (1971) | – | 0.58 | 1.47 | – |
| | Moffat (1972) | 8.0 | 0.56 | 1.70 | – |
| | Glushkova et al. (1999) | – | 0.12 | 1.24 | – |
| | Dias et al. (2002) | 7.57 | 0.50 | 1.64 | – |
| | Kharchenko et al. (2005) | 7.52 | 0.50 | 1.64 | – |
| | Paunzen & Mermilliod (2007) | 7.57 | 0.50 | 1.64 | – |
| | PP | 7.69 | 0.63 | 1.88 | +0.13 |
| NGC 6811 | Luo et al. (2009) | 8.76 | 0.12 | 1.31 | +0.02 |
| | Paunzen & Mermilliod (2007) | 8.80 | 0.16 | 1.22 | – |
| | PP | 8.27 | 0.14 | 1.64 | −0.02 |

studies of proper motion, photometry and position of the stars. Membership probabilities, if compared with those of Sanders' (1971), are in rough agreement: all but two stars (W92 and W146) that we assign cluster membership are not assigned as members according to Sanders' probabilities, but it is equally true that those which we define as non-members are determined to be members by Sanders (1971). When the comparison is done with those probabilities of the compilation of Kharchenko et al. (2005) the conclusions are equally in agreement. There are two stars, W18 and W45 we define as members that Kharchenko et al. (2005) find to be non-members from the proper motion studies but members with the other two criteria. In conclusion, the comparison of our results with the others support our findings particularly because the results obtained from $uvby-\beta$ photometry are more accurate.

The DM and reddening determined from our photometry, although discordant from those derived from $UBV$ photometry, is in agreement with that of Glushkhova, Batyrshinova, & Ibragimov (1999) who, from radial velocity measurements for 60 late-type stars and $UBVRI$ photoelectric photometry refined the distance modulus of the cluster to be $10.47 \pm 0.08$ mag and $E(B-V)$ of $0.12 \pm 0.02$, in agreement with the values we derived.

We were able to determine membership to the NGC 6811 open cluster of several variable stars. We found that six stars V1, V4, V10, V11, V13 and V16 are cluster members. On the contrary, V12, V14 and V15 are definitely non-member stars. For the rest not much can be said. Accurate temperature determination was done for each star.

NGC 6830. Again, since no previous $uvby-\beta$ exists, knowledge of the cluster rests on $UBV$ photometry. Both the color-color and the color-magnitude diagrams do not show a clear main sequence which make the distance, age and reddening determinations ambiguous. We only measured nineteen stars, but with this small sample we determined some clustering of stars. Our findings coincide, within the uncertainties, with the previous distance, reddening and age determinations. Of course, many more data are needed to unambiguously establish the true nature of this cluster, but we emphasize that, since we observed all the bright stars, our conclusions are correct.

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TABLE 8

CROSS ID AND MEMBERSHIP PROBABILITIES FOR THE OPEN CLUSTER NGC 6811

| WBD | Luo et al. (2009) | Sanders (1971) | Becker (1947) | Barkhatova et al. (1978) | Kharchenko (2005) | Prob (Sanders) | Prob (Kharchenko) Pkin | Pph | Psp | mbr |
|---|---|---|---|---|---|---|---|---|---|---|
| 112 | | 177 | 51 | 1136 | | 0 | | | | nm |
| 122 | | | | | | | | | | nm |
| 107 | | 183 | 48 | | | 96 | | | | nm |
| 31 | | 102 | 15 | 1057 | | 97 | | | | m |
| 489 | 6 | 205 | | 2080 | | 89 | | | | m |
| 146 | | 187 | 42 | 1143 | | 0 | | | | m |
| 68 | | 110 | 86 | 1065 | 78 | 97 | 0.9272 | 1 | 1 | m |
| 34 | | 121 | 22 | 1084 | | 96 | | | | m |
| 105 | | 185 | 47 | 1141 | | 25 | | | | m |
| 85 | | 94 | 4 | 1041 | | 95 | | | | m |
| 218 | | 192 | | 1154 | | 92 | | | | m |
| 106 | | 172 | 49 | 1133 | | 97 | | | | m |
| 47 | | 158 | 35 | 1121 | | 96 | | | | m |
| 37 | 2 | 136 | 26 | 1104 | | 96 | | | | m |
| 147 | | 189 | 43 | 1146 | | 97 | | | | m |
| 70 | 3 | 108 | 82 | 1063 | 76 | 96 | 0.9837 | 1 | 1 | m |
| 86 | | 98 | 5 | 1050 | | 89 | | | | m |
| 26 | | 86 | 10 | 1038 | 69 | 97 | 0.4193 | 1 | 1 | m |
| 99 | | 159 | 29 | 1122 | | 97 | | | | m |
| 18 | 1 | 97 | 85 | 1049 | 73 | 97 | 0.0016 | 1 | 1 | m |
| 115 | | 149 | 65 | | | 95 | | | | m |
| 16 | | 103 | 81 | 1059 | | 90 | | | | m |
| 54 | | 147 | 68 | 1114 | | 97 | | | | m |
| 113 | 5 | 166 | 60 | 1126 | 98 | 93 | 0.8128 | 1 | 1 | m |
| 92 | | 115 | 20 | 1071 | | 0 | | | | m |
| 46 | | 160 | 36 | 1124 | | 96 | | | | m |
| 33 | 13 | 113 | 19 | 1066 | 79 | 95 | 0.9765 | 0.9971 | 1 | m |
| 114 | | 146 | 66 | | | 96 | | | | m |
| 49 | | 165 | 46 | 1125 | 97 | 93 | 0.7504 | 1 | 1 | m |
| 5 | | 127 | 25 | 1092 | 83 | 93 | 0.9227 | 0.7357 | 1 | m |
| 9 | 16 | 134 | 71 | 1101 | 86 | 88 | 0.9565 | 1 | 1 | m |
| 62 | | 123 | 77 | 1087 | | 97 | | | | m |
| 139 | | 131 | | 1096 | | 95 | | | | m |
| 44 | 11 | 157 | 33 | 1120 | 95 | 96 | 0.9137 | 1 | 1 | m |
| 53 | 10 | 135 | 69 | 1105 | | 94 | | | | m |
| 45 | | 155 | 34 | 1118 | 94 | 97 | 0.0001 | 0.6244 | 1 | m |
| 78 | | 72 | 11 | 1023 | | 95 | | | | m: |
| 39 | 4 | 144 | 30 | 1112 | | 54 | | | | nm |
| 41 | | 154 | 28 | 1117 | | 0 | | | | nm |
| 8 | | | | 1106 | | | | | | nm |
| 56 | | 138 | 67 | 1108 | 89 | 0 | 0.7463 | 0.9707 | 1 | nm |
| 36 | | 132 | | 1099 | | 97 | | | | nm |
| 42 | 14 | 143 | 31 | 1111 | | 90 | | | | nm |
| 4 | 12 | 119 | 23 | 1077 | | 95 | | | | nm |
| 51 | 15 | 137 | 70 | 1109 | | 97 | | | | nm |
| 43 | | 142 | 32 | 1110 | | 96 | | | | nm |
| 40 | | | | | | | | | | nm |
| 6 | | | | 1093 | | | | | | und |
| 7 | | | | 1102 | | | | | | und |
| 10 | | | | 1085 | | | | | | und |
| 12 | | | | 1078 | | | | | | und |
| 13 | | | | 1082 | | | | | | und |
| 14 | | 114 | 80 | 1067 | | 0 | | | | und |
| 22 | | 84 | 18 | 1029 | | 0 | | | | und |
| 23 | 18 | | 17 | 1053 | | | | | | und |
| 24 | | 95 | 14 | 1047 | 72 | 97 | 0.8117 | 1 | 1 | und |
| 32 | | 106 | 16 | 1061 | | 97 | | | | und |
| 35 | | 128 | | 1095 | | 80 | | | | und |
| 38 | | 150 | 27 | 1115 | | 0 | | | | und |
| 57 | | 129 | 72 | 1097 | | 79 | | | | und |
| 58 | | 130 | 73 | 1098 | | 71 | | | | und |
| 63 | | | | | | | | | | und |
| 64 | | | | | | | | | | und |
| 65 | | 120 | 78 | 1081 | | 96 | | | | und |
| 71 | | 77 | 100 | 1026 | 66 | 97 | 0.5865 | 1 | 1 | und |
| 73 | | 64 | 101 | 1016 | 61 | 0 | 0.0646 | 1 | 1 | und |
| 74 | | 74 | 13 | | | 0 | | | | und |
| 77 | | 67 | 12 | 1018 | | 97 | | | | und |
| 79 | | 85 | 1 | 1031 | 68 | 0 | 0.4112 | 1 | 1 | und |
| 82 | | 89 | 3 | 1036 | | 27 | | | | und |
| 87 | | 100 | 7 | 1054 | | 57 | | | | und |
| 101 | | 170 | 38 | 1131 | 87 | 97 | 0.8326 | 1 | 1 | und |
| 102 | | 179 | 40 | 1137 | | 0 | | | | und |
| 145 | 64 | 1113 | | 0 | | | | | | und |
| 123 | | | | 1051 | | | | | | und |
| 133 | | 92 | 2 | 1039 | 71 | 94 | 0.8766 | 1 | 1 | und |
| 178 | | 76 | 99 | 1025 | 65 | 96 | 0.8519 | 0.9999 | 1 | und |
| 491 | 7 | 209 | | | | 0 | | | | und |
| v17 | | | | | | | | | | und |

## REFERENCES

Arellano-Ferro, A., & Parrao, L. 1988, Reporte Técnico, 57 (México: IA-UNAM)
Barkhatova, K. A. 1957, Soviet Astron., 1, 822
Barkhatova, K. A., Zakharova, P. E., & Shashkina, L. P. 1978, AZh, 55, 56
Becker, W. 1947, Astron. Nachr., 275, 229
Becker, W., & Fenkart, R. 1971, A&AS, 4, 241
Borucki, W. J., Koch, D. G., Dunham, E. W., & Jenkins, J. M. 1997, in ASP Conf. Ser. 119, Planets Beyond the Solar System and the Next Generation of Space Missions, ed. D. Soderblom (San Francisco: ASP), 153
Crawford, D. L., & Mander, J. 1966, AJ, 71, 114
Dias, W. S., Alessi, B. S., Moitinho, A., & Lepine, J. R. D. 2002, A&A, 389, 871
Fox Machado, L., Pérez Hernández, F., Suárez, J. C., Michael, E., & Lebreton, Y. 2006, A&A, 446, 611
Fox Machado, L., et al. 2001, in Helio- and Asteroseismology at the Dawn of the Millennium, ed. A. Wilson (ESA SP-464; Noordwijk: ESA), 427
Fox Machado, L., et al. 2002, A&A, 382, 556
Girardi, L., et al. 2003, Mem. Soc. Astron. Italiana, 74, 474
Glushkova, E. V., Batyrshinova, V. M., & Ibragimov, M. A. 1999, Astron. Lett., 25, 86
Golay, M. 1974, Introduction to Astronomical Photometry (Dordrecht: Reidel)
Grönbech, B., Olsen, E. H., & Strömgren, B. 1976, A&AS, 26, 155
Hoag, A. A., & Applequist, N. L. 1965, ApJS, 12, 215
Kharchenko, N. V., Piskunov, A. E., Röser, S., Schilbach, E., & Scholz, R. D. 2005, A&A, 438, 1163
Lester, J. B., Gray, R. O., & Kurucz, R. I. 1986, ApJ, 61, 509 (LGK86)
Li, Z. P., et al. 2002, A&A, 395, 873
Li, Z. P., et al. 2004, A&A, 420, 283
Lindoff, U. 1972, A&A, 16, 315
Luo, Y. P., Zhang, X. B., Luo, C. Q., Deng, L. C., & Luo, Z. Q. 2009, New Astron., 14, 584
Meynet, G., Mermilliod, J. C., & Maeder, A. 1993, A&AS, 98, 477
Moffat, A. F. J. 1972, A&AS, 7, 355
Netopil, M., et al. 2007, A&A, 462, 591
Nissen, P. 1988, A&A, 199, 146
Olsen, E. H. 1983, A&AS, 54, 55
Paunzen, E., & Mermilliod, J. C. 2007, WEBDA: A Site Devoted to Stellar Clusters in the Galaxy and the Magellanic Clouds (Vienna: Institute of Astronomy of the University of Vienna) http://www.univie.ac.at/webda/
Peña, J. H., Fox Machado, L., & Garrido, R. 2007, RevMexAA, 43, 329
Peña, J. H., García-Cole, A., Hobart, M., De la Cruz, C., Plascencia, J. C., & Peniche, R. 2003, RevMexAA, 39, 171
Peña, J. H., & Peniche, R. 1994, RevMexAA, 28, 139
Peña, J. H., & Sareyan, J. P. 2006, RevMexAA, 42, 179
Peña, J. H., et al. 1998, A&AS, 129, 9
Rose, M. B., & Hintz, E. G. 2007, AJ, 134, 2067
Sanders, W. L. 1971, A&A, 15, 368
Shobbrook, R. R. 1984, MNRAS, 211, 659
Turner, D. G. 1976, AJ, 81, 1125
van Cauteren, P., Lampens, P., Robertson, C. W., & Strigachev, A. 2005, Commun. Asteroseismol., 146, 21

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