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# $uvby - \beta$ PHOTOELECTRIC PHOTOMETRY OF THE OPEN CLUSTERS NGC 1647 AND NGC 1778

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RESUMEN

Se presenta fotometría $uvby - \beta$ de 35 estrellas en la dirección del cúmulo abierto NGC 1647 y de 16 estrellas del cúmulo NGC 1778. Del análisis de los datos obtenidos para NGC 1647 se ha determinado un enrojecimiento $E(b-y) = 0.32 \pm 0.02$ mag y un módulo de distancia de $V_0 - M_V = 8.75 \pm 0.09$ correspondiente a una distancia $d = 564 \pm 106$ pc; asimismo, se han encontrado las estrellas miembros y se ha determinado un valor numérico para la edad del cúmulo de log edad (en años) = $7.98 \pm 0.23$. A partir del análisis de los datos obtenidos para NGC 1778, se concluye que no es posible determinar si hay un cúmulo en esa dirección, pues las distancias encontradas para las estrellas observadas son muy diferentes.

ABSTRACT

We present photometry $uvby - \beta$ for 35 stars in the direction of the open cluster NGC 1647 and for 16 stars in the direction of the cluster NGC 1778. From the analysis of the data obtained for NGC 1647 we determine a mean reddening of $E(b-y) = 0.32 \pm 0.02$ mag and a distance modulus of $V_0 - M_V = 8.75 \pm 0.09$ corresponding to a distance $d = 564 \pm 106$ pc; also, we find the cluster member stars and a numerical value of log age (in years) = $7.89 \pm 0.23$. From the analysis of data obtained for NGC 1778, we conclude that it is not possible to determine whether there is a cluster in that direction, because the distances found for the observed stars are very different.

*Key Words:* open clusters and associations: individual (NGC 1647, NGC 1778) — techniques: photometric



## 1. INTRODUCTION

Galactic open clusters are ensembles of stars with low concentration and irregular shape, gravitationally-bound systems formed at the same time from the same original cloud. They represent examples of stars of comparable age and intrinsic chemical composition and are important in the study of stellar evolution and star formation. As a consequence, the problem of determining the cluster member stars is very important. For this, it is necessary to know the distance, reddening and absolute magnitude of each star.

The present work studies two open clusters, NGC 1647 and NGC 1778, using Strömgren photometry ($uvby - \beta$) to determine their parameters: reddening, distance modulus and age. The results will be compared with those obtained from the Johnson photometry taken from the literature.

Based on the individual distances of the stars, we will determine whether they belong to the cluster. There are other important physical characteristics in the study of stellar evolution to characterize a star cluster namely temperature and surface gravity of the stars. Using them we can determine the clusters' age (Meynet, Mermilliod, & Maeder 1993).

NGC 1647 is situated beyond the Taurus dark cloud complex, only a few degrees from the Hyades cluster. The center equatorial coordinates are $\alpha(2000) = 4^h 46^m 8^s.45$ and $\delta(2000) = +19°04'37''$. The diameter of the cluster is about $45'$ and it is a relatively rich cluster that has not been studied by $uvby - \beta$ photometry. Other authors have reported physical parameters (Table 1): Hoag & Applequist (1965) observed 65 stars and reported a distance $d = 549$ pc, a reddening $E(B-V) = 0.30$ and

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TABLE 1

COMPARISON OF PARAMETERS, NGC 1647

| Parameter | Paunzen[a] | Hoag[b] | Turner[c] | Hebb[d] | Zdanavičius[e] | Guerrero[f] |
|---|---|---|---|---|---|---|
| $E(B-V)$ | 0.370 | 0.30 | 0.29 | 0.37 | 0.35 | 0.35 |
| $V_0 - M_V$ | 9.81 | 8.7 | 8.67 | 8.7 | 8.42 | 8.75 |
| $d$ (pc) | 540 | 549 | 542 | 550 | 555 | 564 |
| log age | 8.158 | – | 8.27 | 8.3 | 8.1 | 7.98 |

[a]Paunzen & Mermilliod (2007). [b]Hoag & Applequist (1965). [c]Turner (1992). [d]Hebb et al. (2004). [e]Zdanavičius et al. (2005). [f]This paper.

TABLE 2

COMPARISON OF PARAMETERS, NGC 1778

| Parameter | Paunzen[a] | Hoag[b] | Barbon[c] | Joshi[d] | Pandey[e] | Xin[f] |
|---|---|---|---|---|---|---|
| $E(B-V)$ | 0.33 6 | 0.34 | 0.33 | 0.34 | 0.23 | 0.23 |
| $V_0 - M_V$ | 11.88 | 10.7 | 11.11 | 10.3 | 10.2 | 11.53 |
| $d$ (pc) | 1469 | 1380 | 1670 | 1062 | 1100 | 2023 |
| log age | 8.155 | – | – | 8.2 | 11.3 | 11.8 |

[a]Paunzen & Mermilliod (2007). [b]Hoag & Applequist (1965). [c]Barbon & Hassan (1973). [d]Joshi et al. (1975). [e]Pandey (1998). [f]Xin et al. (2007).



a distance modulus $V_0 - M_V = 8.7$. Using Johnson photometry Turner (1992) observed 45 stars, reported a distance $d = 542 \pm 4$ pc, and measured a reddening $E(B-V) = 0.29 \pm 0.01$, a distance modulus $V_0 - M_V = 8.67 \pm 0.02$ and an age log age = 8.27 years. Hebb, Wyse, & Gilmore (2004) with 53 stars determined a distance $d = 550$ pc, a reddening $E(B-V) = 0.37$, a distance modulus $V_0 - M_V = 8.7$ and an age log age = 8.3 years. Using the Vilnius seven-color photometric system, Zdanavičius et al. (2005) published a study of 252 stars and reported a distance $d = 555 \pm 74$ pc, a reddening $E(B-V) = 0.35 \pm 0.01$, a distance modulus $V_0 - M_V = 8.42 \pm 0.02$ and an age log age = 8.1 years.

NGC 1778 lies in the direction of the Perseus arm; the coordinates for its center are: $\alpha(2000) = 5^h08^m04^s.56$ and $\delta(2000) = +37°01'24''$. The diameter of the cluster is about 10′ and it is a very poorly populated, faint cluster, which has no previously observed $uvby-\beta$ photometry. Other authors have reported physical parameters (Table 2): Hoag & Applequist (1965) observed 10 stars and reported a distance $d = 1380$ pc, a reddening $E(B-V) = 0.34$ and a distance modulus of $V_0 - M_V = 10.7$, using Johnson photometry. In 1973, Barbon & Hassan observed 14 stars and reported a distance $d = 1670$ pc, a reddening $E(B-V) = 0.33$ and a distance modulus $V_0 - M_V = 11.11$. Joshi, Sagar, & Pandey (1975) observed 85 stars and reported a reddening $E(B-V) = 0.34$, a distance $d = 1062$ pc, a distance modulus $V_0 - M_V = 10.13$ and an age log age = 8.2 years. Pandey (1998) observed 16 stars and reported a distance $d = 1100$ pc, a distance modulus $V_0 - M_V = 10.2$ and an age log age = 11.3 years. Xin, Deng, & Han (2007) using 15 stars determined a distance $d = 2023$ pc, a reddening $E(B-V) = 0.23$, a distance modulus $V_0 - M_V = 11.53$ and an age log age = 11.18 years.

## 2. OBSERVATIONS

Observations were made at the Observatorio Astronómico Nacional, San Pedro Mártir, Mexico, with the 1.5 m telescope and a Strömgren spectrophotometer. The observing run consisted of five nights from 22 to 26 in October 2007. We chose to observe all the brightest stars up to magnitude 13 (close to the limit of the telescope-photometer system), according to the chart of Paunzen & Mermilliod (2007, WEBDA, magnitude limit 13).

In order to be able to transform the data into the $uvby-\beta$ absolute system, a set of photometric standards was observed along with the program stars.

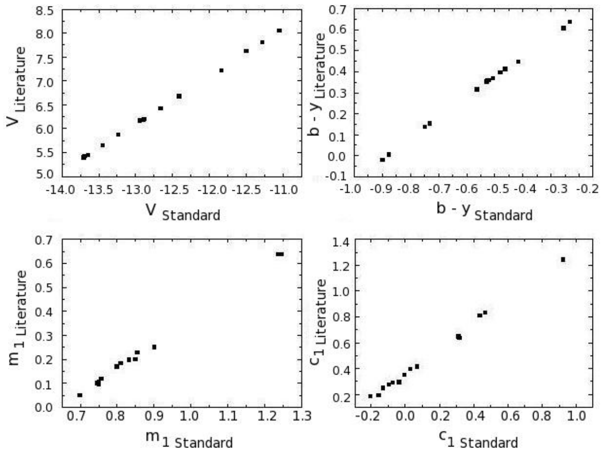


Fig. 1. Sample of the transformation correlations between instrumental and standard values for a group of standard stars for the October, 2007 season.

### 2.1. *Data acquisition*

Each measurement consisted of five ten-second integrations for each star. The obtained values of the standard stars and for all the observed bright stars are the average of these measurements. A ten-second integration of the sky was subtracted from the *uvby* filters and from the N and W filters that define H$\beta$. Individual uncertainties were determined by calculating the standard deviations of the fluxes in each filter for each star. The precision of each measurement is a function of both the brightness and the spectral type of each star, but we tried to observe them long enough to obtain a sufficient number of source counts to ensure a signal/noise ratio $N/\sqrt{(N)}$ close to a 0.01 mag accuracy.

Seasonal errors were evaluated through the diferences (calculated minus reported) of the magnitude and colors for the standard stars. Ten to fifteen standard stars were observed each night. Emphasis is made on the large range in the magnitude and color values of the standard stars (see Figure 1).

### 2.2. *Data reduction*

Standard data reduction procedures have been done with the numerical package NABAPHOT (Arellano Ferro & Parrao 1988). The chosen system was that defined by the standard values of Olsen (1983), and we also took some bright standard stars from the Astronomical Almanac (2006). The transformation equations (1–5) are those given by Crawford & Barnes (1970) and by Crawford & Mander (1966); in these equations $D$, $F$, $H$ and $L$ are the slope coefficients for $(b-y)$, $m_1$, $c_1$ and $\beta$, respectively. $B$, $J$ and $I$ are the color term coefficients of $V$, $m_1$ and $c_1$. The errors are calculated through the standard stars observed, evaluating the differences in magnitude and colors between the derived values and those of the literature. These differences for $V$, $(b-y)$, $m_1$, $c_1$ and $\beta$ are $\pm0.010$, $\pm0.006$, $\pm0.007$, $\pm0.021$ and $\pm0.004$ respectively, providing a numerical estimation of our uncertainties when transforming into the standard system.

$$V = 19.096 + 1.000(b-y) + y_{\rm obs}, \quad (1)$$

$$(b-y) = -0.002 + 0.867(b-y)_{\rm obs}, \quad (2)$$

$$m_1 = 0.981 + 0.001(m_1)_{\rm obs} + 0.375(b-y), \quad (3)$$

$$c_1 = -0.648 + 1.044(c_1)_{\rm obs} + 0.042(b-y), \quad (4)$$

$${\rm H}\beta = 2.978 + 1.237({\rm H}\beta)_{\rm obs}. \quad (5)$$

Table 3 lists the photometric values of the observed stars of NGC 1647 and Table 4 the values of the NGC 1778 stars, ordered by decreasing $\beta$ values. Column 1 reports the WEBDA ID of the stars as listed by Paunzen & Mermilliod (2007), Columns 2 to 5 the Strömgren values $V$, $(b-y)$, $m_1$, and $c_1$ respectively; Column 6, the $\beta$ value, Columns 7 and 8, the reddening-free indexes $[m_1]$ and $[c_1]$ (independent of interstellar extinction) derived from the observations. Column 9 lists the spectral types reported by Paunzen & Mermilliod (2007), and Column 10 the photometric spectral type obtained from the diagram $[c_1] - [m_1]$.

## 3. METHODOLOGY

When studying a cluster it is important to establish membership of its star on a star-by-star basis, taking advantage of the Strömgren photometry, with the calibrations made by Nissen (1988) based on the calibrations by Crawford (1975, 1979) for the A and F stars and by Shobbrook (1984) for early type stars. In the present study the determination of physical parameters, such as the effective temperature and surface gravity, has been done through the measured Strömgren photometric data in the standard system, once corrected for interstellar extinction. Theoretical $uvby-\beta$ indexes, such as those of Lester, Gray, & Kurucz (1986, hereinafter LGK86), allowed us to directly compare our photometry with that obtained theoretically. LGK86 calculated grids for stellar atmospheres for G, F, A, B and O stars in a temperature range from 5500 K up to 50000 K; they also calculated $\log g$ and $T_{\rm eff}$ as a function of the Strömgren indexes. The determination was done in the $(b-y)$ versus $\beta$ diagram and in the $[c_1]$ versus $\beta$ diagram (Figure 2).

The evaluation of reddening was done by establishing to which spectral class each star belongs:

TABLE 3

$uvby - \beta$ PHOTOELECTRIC PHOTOMETRY OF NGC 1647

| WEBDA | $V$ | $b-y$ | $m_1$ | $c_1$ | $[m_1]$ | $[c_1]$ | $\beta$ | MK | ST |
|---|---|---|---|---|---|---|---|---|---|
| 2 | 7.465 | 0.996 | 0.510 | 0.245 | 0.828 | 0.045 | 2.893 | K0 | late |
| 10 | 11.052 | 0.398 | 0.035 | 0.979 | 0.162 | 0.899 | 2.892 | B7.5IV | B9 |
| 68 | 10.150 | 0.361 | 0.117 | 0.995 | 0.232 | 0.922 | 2.889 | | A3 |
| 71 | 10.671 | 0.312 | 0.054 | 0.941 | 0.153 | 0.878 | 2.864 | A0 | B9 |
| 34 | 10.593 | 0.257 | 0.061 | 0.900 | 0.143 | 0.848 | 2.851 | B9 | B9 |
| 42 | 9.667 | 0.246 | 0.077 | 0.912 | 0.155 | 0.862 | 2.850 | B9.5IV | B9 |
| 29 | 10.674 | 0.259 | 0.062 | 0.967 | 0.144 | 0.915 | 2.838 | A0 IV | B9 |
| 49 | 10.048 | 0.290 | 0.083 | 0.945 | 0.175 | 0.887 | 2.832 | B8 | B8 |
| 31 | 10.264 | 0.219 | 0.082 | 0.905 | 0.152 | 0.861 | 2.794 | B8 | B9 |
| 48 | 10.402 | 0.247 | 0.075 | 0.825 | 0.154 | 0.775 | 2.778 | A0 | B8 |
| 5 | 10.220 | 0.358 | 0.056 | 0.660 | 0.170 | 0.588 | 2.774 | A0 | B6 |
| 37 | 8.864 | 0.246 | 0.040 | 0.651 | 0.118 | 0.601 | 2.774 | B9.5IV | B5 |
| 57 | 9.985 | 0.333 | 0.041 | 0.691 | 0.147 | 0.624 | 2.772 | A0 | B5 |
| 70 | 10.466 | 0.288 | 0.062 | 0.707 | 0.154 | 0.649 | 2.767 | B9 | B6 |
| 419 | 9.811 | 0.197 | 0.047 | 0.629 | 0.110 | 0.589 | 2.756 | | B4 |
| 51 | 9.943 | 0.303 | 0.080 | 0.766 | 0.177 | 0.705 | 2.753 | B9 IV | B7 |
| 99 | 10.059 | 0.327 | 0.044 | 0.794 | 0.148 | 0.728 | 2.753 | B9 IV | B7 |
| 54 | 10.075 | 0.290 | 0.053 | 0.654 | 0.145 | 0.596 | 2.746 | A0 V | B5 |
| 22 | 9.067 | 0.199 | 0.042 | 0.739 | 0.105 | 0.699 | 2.742 | B9 II | B6 |
| 59 | 9.698 | 0.400 | 0.008 | 0.773 | 0.136 | 0.693 | 2.738 | A0 | B7 |
| 3 | 10.026 | 0.290 | 0.055 | 0.656 | 0.147 | 0.598 | 2.736 | B7.5IV | B4 |
| 94 | 9.667 | 0.216 | 0.047 | 0.666 | 0.116 | 0.622 | 2.726 | B9 III | B5 |
| 55 | 10.246 | 0.341 | 0.040 | 0.632 | 0.149 | 0.563 | 2.724 | B7 V | B4 |
| 66 | 10.246 | 0.350 | 0.017 | 0.913 | 0.129 | 0.843 | 2.721 | B8 | B8 |
| 233 | 10.136 | 0.254 | 0.092 | 0.571 | 0.173 | 0.520 | 2.708 | | B4 |
| 102 | 9.307 | 0.281 | 0.026 | 0.770 | 0.115 | 0.713 | 2.702 | B9 III | B6 |
| 45 | 8.860 | 0.248 | 0.039 | 0.645 | 0.118 | 0.595 | 2.700 | B7.5IV | B4 |
| 44 | 9.213 | 0.231 | 0.033 | 0.769 | 0.106 | 0.722 | 2.697 | B8 IV | B8 |
| 15 | 8.561 | 0.304 | 0.020 | 0.644 | 0.117 | 0.583 | 2.620 | B8 III | B4 |
| 65 | 9.561 | 0.364 | 0.153 | 0.34 | 0.269 | 0.267 | 2.611 | G0 | late |
| 105 | 8.391 | 1.048 | 0.556 | 0.214 | 0.891 | 0.004 | 2.585 | K2 | late |
| 1 | 5.963 | 0.727 | 0.694 | 0.280 | 0.926 | 0.134 | 2.562 | K0 | late |
| 84 | 8.779 | 1.084 | 0.840 | 0.088 | 1.186 | −0.128 | 2.553 | K5 | late |
| 16 | 9.480 | 0.496 | 0.232 | 0.449 | 0.39 | 0.349 | 2.548 | K0 V | late |



early (B or early A) or late (late A or F) types; the later-class stars (later than G) were not considered in the analysis since no reddening determination calibration has yet been developed for such MS stars. Further analyses were done considering the numerical criteria of Lindroos (1980) for Strömgren photometry.

## 4. RESULTS

The application of the above mentioned numerical packages gave the results listed in Table 5 for NGC 1647 and Table 6 for NGC 1778. The following values are listed: the WEBDA identificator, the reddening, $E(b-y)$, the reddening-free indexes (in decreasing $\beta$ values), the absolute magnitude, the distance modulus, the distance (in parsecs), the effective temperature and the surface gravity. When histograms of the distances are drawn (Figure 3a), one can see that 24 of the 35 observed stars in NGC 1647 lie around a distance of 564 pc corresponding to a distance modulus of $8.75 \pm 0.09$. However, when the histogram of distances to the stars is plotted for

TABLE 4

$uvby-\beta$ PHOTOELECTRIC PHOTOMETRY OF NGC 1778

| WEBDA | $V$ | $b-y$ | $m_1$ | $c_1$ | $[m_1]$ | $[c_1]$ | $\beta$ | MK | ST |
|---|---|---|---|---|---|---|---|---|---|
| 46 | 13.014 | 0.570 | 0.150 | 0.380 | 0.330 | 0.270 | 2.830 | | late |
| 33 | 10.975 | 0.250 | 0.020 | 0.950 | 0.100 | 0.900 | 2.828 | A0 | B9 |
| 36 | 11.527 | 0.240 | 0.050 | 0.720 | 0.120 | 0.680 | 2.764 | | B6 |
| 8 | 11.794 | 0.250 | −0.086 | 0.750 | 0.280 | 0.700 | 2.753 | | late |
| 5 | 11.150 | 0.240 | 0.010 | 0.710 | 0.090 | 0.660 | 2.744 | B9.5IV | B5 |
| 39 | 11.681 | −0.200 | 0.320 | 0.810 | 0.250 | 0.850 | 2.740 | B7 IV-V | A3 |
| 41 | 11.964 | 0.250 | 0.010 | 0.620 | 0.090 | 0.570 | 2.740 | | B4 |
| 32 | 10.283 | 0.240 | −0.010 | 0.640 | 0.070 | 0.590 | 2.729 | B6 III-IV | B3 |
| 3 | 10.190 | 0.480 | 0.110 | 0.600 | 0.270 | 0.500 | 2.699 | B6 IV | late |
| 141 | 11.285 | 0.230 | −0.065 | 0.530 | 0.070 | 0.490 | 2.671 | | B2 |
| 7 | 11.810 | 0.280 | −0.030 | 0.840 | 0.060 | 0.780 | 2.664 | B6 IV-V | B6 |
| 31 | 10.197 | 0.270 | −0.020 | 0.840 | 0.070 | 0.780 | 2.623 | B9 III | B6 |
| 37 | 11.599 | 0.470 | 0.150 | 0.360 | 0.300 | 0.260 | 2.617 | | late |
| 140 | 9.638 | 0.280 | −0.040 | 0.630 | 0.050 | 0.570 | 2.614 | A0 | B3 |
| 2 | 10.104 | 0.860 | 0.370 | 0.360 | 0.640 | 0.190 | 2.585 | G8 III | late |
| 34 | 11.437 | 1.000 | 0.560 | 0.310 | 0.880 | 0.110 | 2.579 | | late |

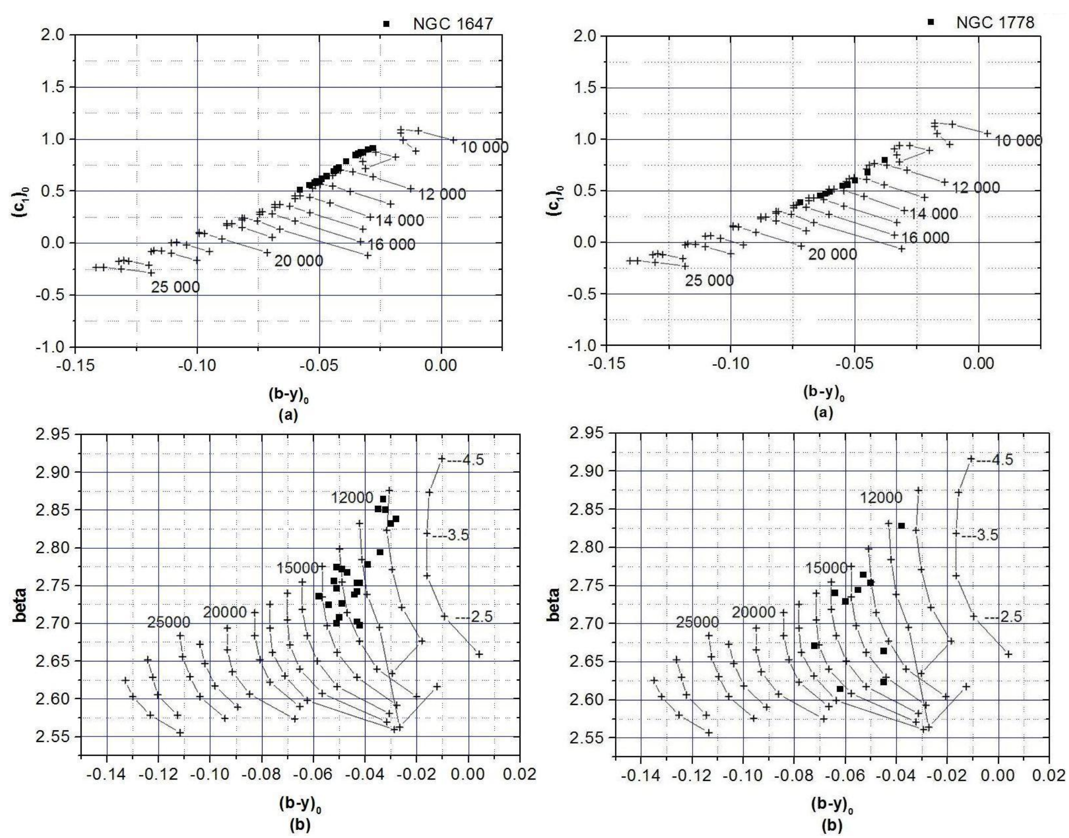


Fig. 2. Left panels (a) LGK86 isotherms for NGC 1647. (b) LGK86 isogravities for NGC 1647. Right panels (a) LGK86 isotherms for NGC 1778. (b) LGK86 isogravities for NGC 1778.

TABLE 5

REDDENING AND UNREDDENED PARAMETERS OF NGC 1647

| WEBDA | $E(b-y)$ | $(b-y)_0$ | $(m_1)_0$ | $(c_1)_0$ | H$\beta$ | $V_0$ | $M_V$ | DM | dist $(pc)$ | $T_{\rm eff}$ (K) | $\log g$ | membership |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 94 | 0.428 | −0.030 | 0.163 | 0.898 | 2.892 | 9.21 | 1.23 | 7.98 | 395 | 11000 | 4.0 | n |
| 71 | 0.343 | −0.033 | 0.162 | 0.870 | 2.864 | 9.20 | 0.98 | 8.22 | 440 | 11000 | 4.5 | y |
| 34 | 0.292 | −0.035 | 0.148 | 0.845 | 2.851 | 9.34 | 0.86 | 8.48 | 496 | 11000 | 4.5 | y |
| 42 | 0.284 | −0.032 | 0.162 | 0.874 | 2.850 | 9.04 | 0.84 | 8.21 | 438 | 11000 | 4.5 | y |
| 29 | 0.287 | −0.028 | 0.148 | 0.912 | 2.838 | 9.44 | 0.68 | 8.76 | 564 | 11000 | 4.0 | y |
| 49 | 0.325 | −0.030 | 0.181 | 0.900 | 2.832 | 8.65 | 0.62 | 8.03 | 404 | 11000 | 4.0 | y |
| 31 | 0.253 | −0.034 | 0.158 | 0.857 | 2.794 | 9.18 | 0.18 | 9.00 | 632 | 11000 | 3.5 | y |
| 48 | 0.293 | −0.039 | 0.164 | 0.784 | 2.778 | 9.14 | 0.02 | 9.12 | 667 | 12000 | 3.5 | y |
| 5 | 0.417 | −0.051 | 0.170 | 0.594 | 2.774 | 8.46 | 0.07 | 8.39 | 476 | 13000 | 4.0 | y |
| 37 | 0.341 | −0.051 | 0.157 | 0.591 | 2.774 | 8.56 | 0.07 | 8.50 | 501 | 13000 | 4.0 | y |
| 57 | 0.382 | −0.049 | 0.155 | 0.618 | 2.772 | 8.34 | 0.04 | 8.31 | 459 | 13000 | 4.0 | y |
| 70 | 0.335 | −0.047 | 0.162 | 0.643 | 2.767 | 9.03 | −0.04 | 9.06 | 649 | 12000 | 4.0 | y |
| 419 | 0.248 | −0.052 | 0.123 | 0.580 | 2.756 | 8.75 | −0.16 | 8.91 | 605 | 13000 | 4.0 | y |
| 51 | 0.350 | −0.043 | 0.186 | 0.712 | 2.753 | 8.44 | −0.29 | 8.72 | 556 | 12000 | 3.0 | y |
| 99 | 0.369 | −0.042 | 0.155 | 0.724 | 2.753 | 8.47 | −0.30 | 8.77 | 567 | 12000 | 3.5 | y |
| 54 | 0.341 | −0.051 | 0.155 | 0.589 | 2.746 | 8.61 | −0.31 | 8.92 | 607 | 13000 | 3.5 | y |
| 22 | 0.240 | −0.043 | 0.118 | 0.700 | 2.742 | 8.64 | −0.45 | 9.10 | 659 | 12000 | 3.5 | y |
| 59 | 0.444 | −0.044 | 0.141 | 0.689 | 2.738 | 7.80 | −0.51 | 8.31 | 458 | 12000 | 3.5 | y |
| 3 | 0.311 | −0.058 | 0.185 | 0.512 | 2.736 | 8.80 | −0.43 | 9.23 | 701 | 14000 | 4.0 | n |
| 15 | 0.265 | −0.049 | 0.126 | 0.616 | 2.726 | 8.53 | −0.64 | 9.17 | 682 | 13000 | 3.5 | y |
| 55 | 0.395 | −0.054 | 0.158 | 0.557 | 2.724 | 8.55 | −0.63 | 9.18 | 686 | 13000 | 3.5 | y |
| 66 | 0.385 | −0.035 | 0.133 | 0.84 | 2.721 | 8.59 | −1.06 | 9.65 | 851 | 13000 | 3.0 | n |
| 233 | 0.296 | −0.050 | 0.129 | 0.595 | 2.708 | 7.59 | −0.95 | 8.54 | 511 | 13000 | 3.0 | y |
| 102 | 0.324 | −0.043 | 0.123 | 0.708 | 2.702 | 7.91 | −1.24 | 9.16 | 678 | 12000 | 3.0 | y |
| 45 | 0.299 | −0.051 | 0.129 | 0.588 | 2.700 | 7.57 | −1.10 | 8.68 | 544 | 13000 | 3.0 | y |
| 44 | 0.273 | −0.042 | 0.115 | 0.717 | 2.697 | 8.04 | −1.38 | 9.41 | 763 | 12000 | 3.0 | n |
| 10 | 0.356 | −0.052 | 0.127 | 0.576 | 2.620 | 7.05 | −3.63 | 10.68 | 1365 | 13000 | 3.0 | n |

TABLE 6

REDDENING AND UNREDDENED PARAMETERS OF NGC 1778

| WEBDA | $E(b-y)$ | $(b-y)_0$ | $(m_1)_0$ | $(c_1)_0$ | H$\beta$ | $V_0$ | $M_V$ | DM | dist $(pc)$ | $T_{\rm eff}$ (K) | $\log g$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 33 | 0.231 | −0.038 | 0.017 | 0.797 | 2.828 | 9.85 | 0.64 | 9.21 | 695 | 11000 | 4.0 |
| 36 | 0.218 | −0.053 | 0.036 | 0.560 | 2.764 | 10.44 | −0.06 | 10.49 | 1256 | 13000 | 4.0 |
| 8 | 0.242 | −0.050 | −0.013 | 0.600 | 2.753 | 10.39 | −0.21 | 10.60 | 1317 | 13000 | 3.5 |
| 5 | 0.223 | −0.055 | 0.003 | 0.547 | 2.744 | 10.05 | −0.32 | 10.38 | 1189 | 14000 | 3.5 |
| 41 | 0.238 | −0.064 | 0.004 | 0.453 | 2.740 | 10.79 | −0.38 | 11.17 | 1716 | 15000 | 3.5 |
| 32 | 0.243 | −0.060 | −0.007 | 0.490 | 2.729 | 9.10 | −0.53 | 9.63 | 845 | 14000 | 3.0 |
| 141 | 0.263 | −0.072 | 0.014 | 0.388 | 2.671 | 10.16 | −1.53 | 11.70 | 2184 | 16000 | 3.0 |
| 7 | 0.270 | −0.045 | −0.028 | 0.676 | 2.664 | 10.29 | −2.19 | 12.48 | 3137 | 12000 | 2.5 |
| 31 | 0.261 | −0.045 | −0.012 | 0.680 | 2.623 | 8.94 | −3.88 | 12.83 | 3677 | 12000 | 2.0 |
| 140 | 0.286 | −0.062 | −0.016 | 0.472 | 2.614 | 8.24 | −3.54 | 11.79 | 2275 | 14000 | 2.5 |
| 39 | 0.449 | −0.041 | 0.273 | 0.835 | 2.740 | 14.43 | −0.66 | 15.09 | 1043 | 14000 | 2.5 |
| 3 | 0.555 | −0.078 | 0.255 | 0.341 | 2.699 | 7.66 | −1.02 | 8.68 | 545 | 13000 | 30 |
| 37 | 0.502 | −0.101 | 0.234 | 0.147 | 2.617 | 9.28 | −2.86 | 12.14 | 2678 | 12000 | 2.5 |
| 2 | 0.836 | −0.102 | 0.506 | 0.141 | 2.585 | 6.40 | −4.08 | 10.48 | 1247 | 13000 | 3.5 |
| 34 | 1.044 | −0.118 | 0.829 | −0.041 | 2.579 | 7.43 | −4.47 | 11.90 | 2394 | 11000 | 3.0 |

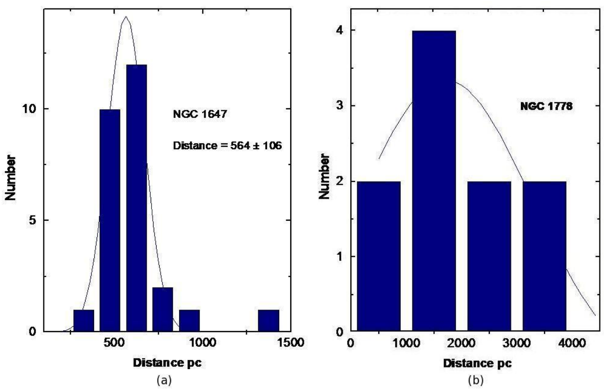


Fig. 3. Histogram of the distances for the stars in the direction of (a) NGC 1647 and (b) NGC 1778. The thin line is a Gaussian fit to the data.

NGC 1778 (Figure 3b), it is not possible to identify a cluster in that direction. We compared the distances obtained photometrically with those derived from studies of proper motions and Hipparcos (1997). However, only two stars in NGC 1647 were observed by Hipparcos; the first star is NGC 1647 15 (HIP 22122), with a parallax 1.66 mas, equivalent to a distance of 602 pc. This distance is consistent, within the error, with 682 pc, a distance that we determined photometrically. The second star observed by Hipparcos is NGC 1647 94 (HIP 22185), with a parallax 3.52 mas, equivalent to a distance 284 pc. This distance is smaller than that determined with photometry (395 pc). However, is still closer than the rest of the stars. For NGC 1647, stars which are members of the cluster are listed un the last column of Table 5; the criterion for those stars is a one sigma deviation from the average.

Once the membership is established, the age can be estimated by first calculating the effective temperature of the hottest stars. These temperatures are determined by plotting the location of such stars on the theoretical grids of LGK86, after evaluating the unreddened colors (Figure 2) for a solar chemical composition. We have considered this metallicity because, although no metallicity has been reported for NGC 1647, the cluster is located within 1.5 kpc from the Sun, i.e., at galactocentric distances where no substantial radial metallicity gradient has been detected (see e.g., Andrievsky et al. 2002). Thus, we can adopt the solar abundance of heavy elements for the cluster and neglect metallicity corrections.

Star 3 is the star with the highest temperature, but based on the distance, we concluded that it does not belong to the cluster. The next hottest star is star 55 because, even though there are several stars with effective temperature of 13000 K, that star has the most negative value of $(b-y)_0$. Hence, given the calibrations of Meynet et al. (1993) for open clusters, a log age of $7.98 \pm 0.23$ (i.e. $9.54 \times 10^7$ yr) is found from the relation log age (yr) $= -3.6 \log T_{\rm eff} + 22.956$, which is valid in the range [3.98, 4.25] of $\log T_{\rm eff}$ (with a precision of $3 \times 10^{-3}$).

In the case of NGC 1778, Hipparcos (1997) also observed only two stars in the cluster. The first star is NGC 1772 5 (HIP 23904), which has a negative parallax, $-0.59$ mas, because the true parallax is smaller than the error. The second star is NGC 1778 2 (HIP 23894), which has a parallax of 2.84 mas, equivalent to a distance of 352 pc, very different from 1247 pc, the distance that we determined. In Table 5 we can see that there is a wide spread in the distances determined by different authors, but Joshi et al. (1975) propose that the difference is due to the fact that they used a revised value of 6.1 for the reddening coefficient $R$ for NGC 1778 (Johnson 1968) because $R$ varies significantly with longitude and galactic extinction in the region $100° < l < 220°$. This value differs from the usually accepted value of $R = 3$, but NGC 1778 has galactic coordinates $l = 168°.88$ and $b = -2°.00$.

## 5. CONCLUSIONS

New $uvby - \beta$ photoelectric photometry has been acquired for 35 stars of the open cluster NGC 1647 and 16 stars of the open cluster NGC 1778. For NGC 1647, unreddened indexes in the LGK86 grids allowed us to determine the effective temperature of the hottest star as 13000 K. We found a mean distance to the cluster of $564 \pm 106$ pc, which corresponds to a distance modulus of $8.75 \pm 0.09$ and a reddening $E(b-y) = 0.32 \pm 0.02$, which, through the relation $E(b-y) = 0.9E(B-V)$, gives a color excess of $E(B-V) = 0.35$ mag. These results are in good agreement with the parameters reported by other authors (Table 1).

In the case of NGC 1778, we were unable to determine whether a cluster in that direction exists or not. NGC 1778 observations include only 16 bright stars and, due to observing limitations, have not reached the cluster MS which is fainter. The determined distance to the stars represented in the histogram (Figure 3b) does not show any clustering of stars. Consequently, we do not have statistically significant data to derive any conclusion regarding this cluster, but based on an earlier and deeper photometric study, it is clear that NGC 1778 is an open star cluster.

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