uvby – β PHOTOELECTRIC PHOTOMETRY OF THE OPEN CLUSTERS
NGC 6811 AND NGC 6830

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Submitted to RevMexAA

RESUMEN

A partir de fotometría fotoeléctrica uvby – β 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 – β 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: PHOTOMETRY - STRÖMGREN PHOTOMETRY - OPEN CLUSTER, VARIABLES, SHORT PERIOD VARIABLES

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 impose 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 and 2004).

A series of Papers (see Peña et al., 1994, 1998, 2003, 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 – β photometry can be done through a comparison with theoretical models (Lester, Gray & Kurucz 1986, hereinafter LGK86).

As a continuation of this study, we now present observations of the open clusters NGC 6811 and NGC 6830. Both clusters have no previous published uvby – β data.

Very recently, Luo et al. (2009) carried out a search for variable stars in the direction of NGC 6811 with CCD photometry in B, and V bands. They detected a total of sixteen variable stars. Among these variables, twelve were catalogued as δ Scuti stars, while no variability type was assigned to the remaining stars. They claim that the twelve δ Scuti stars are all very likely members of the cluster which makes this cluster an interesting target for asteroseismicological 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 + 0.009 from theoretical isochrone fitting to the color magnitude diagram (CMD hereafter) and assuming a metallicity of Z=0.019. They determined the distance modulus and color excess of
of 10.59 ±0.09 and 0.12±0.05, respectively. To the best of our knowledge, no δ Scuti variable stars have been reported in NGC 6830 to date.

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

2. Observations

These were all taken at the Observatorio Astronómico Nacional, México in two different seasons, those of 2009 and of 2010. The dates are listed in Table 1. The 1.5 m telescope to which a spectrophotometer was attached and was utilized at all times. The first observing season was carried out for six nights from June-July 2009. The ID charts utilized were those of WEBDA. When the NGC 6811 data was reduced, there were several stars whose photometry showed large discrepancies with that of the literature. In view of this and due to the fact that several δ 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 − β system.

2.1. Data Acquisition

The following procedure was utilized during all these 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 Hβ. Individual uncertainties were determined by calculating the standard deviations of the fluxes in each filter for each star. The percentual 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/√(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 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 Grönbach, 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), m1, c1 and β, respectively. The coefficients B, J and I are the color terms of V, m1, and c1. 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, m1, c1 and β) 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); m1:(0.09, 0.67); c1:(0.06, 1.12) and β:(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:

\[
V = A + B (b − y) (\text{inst}) + y (\text{inst})
\]

\[
(b − y) (\text{std}) = C + D (b − y) (\text{inst})
\]

\[
m_1(\text{std}) = E + F m_1(\text{inst}) + J (b − y) (\text{inst})
\]

\[
c_1(\text{std}) = G + H c_1(\text{inst}) + I (b − y) (\text{inst})
\]

\[
\beta (\text{std}) = K + L \beta (\text{inst}).
\]

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 and 3 the ID from Sanders (1971) and Luo et al. (2009); the following columns, 4 to 8, the measured photometric values (N denotes the times each star was measured) the three consecutive columns list the unreddened indexes 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). It is interesting to note the agreement between the spectral types deduced from the photometry with that reported by spectroscopic methods. Although there is consistency among the three values, there also is some disagreement among them. For example, W113 has spectroscopic types of A4 and A8 from WEBDA and Becker (1947), respectively and there are some (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 basically the same information as in Table 3, but...
TABLE 1
LOG OF THE OBSERVING SEASONS.

| Epoch       | Cluster          | Initial date   | Final date    | 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 |

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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 upper and NGC 6830, bottom

for NGC 6830. The columns for ID of the variable stars and number of observations have been omitted since each star was measured only once.

2.2. Comparison with other photometries

Since no \( uvby - \beta \) has been previously obtained for these clusters, a comparison of our values is done 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 in which 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 with 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 throw 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 \( V(pp) = 0.82 + 0.97 V(WEBDA) \) 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 in a set constituted of only seven stars. The linear fit between both sets gave the equation \( V(pp) = 0.477 + 0.958 x V(WEBDA) \) with a correlation coefficient of 0.997 and a standard deviation of 0.080. The relationship in B-V and b-y gave \( (b - y) = 0.117 + 0.573 x (B-V) \) 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 (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 criteria. In Tables 3 and 4 the photomet-
rically 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: columns 1 and 2 the ID (WEBDA and Luo et al., 2009) for each star; column 3, the reddening E(b−y); columns 4 to 6, the unreddened indexes (b−y)o, m0, and c0; column 7 the Hβ value, columns 8 and 9 V0, and the absolute magnitude, respectively. Columns 10 and 11 show the distance modulus and the distance in parsecs. The metallicity is presented in column 12 and, finally, column 13 lists the membership to the cluster, denoted by m. 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 semi-colon, m; those that were non-members are denoted by nm. Table 6 is analogous, but no column for variables ID is presented. Probable members are denoted by semicolon, m:

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 ± 1.0 mag, whereas NGC 6830 is merely an association of eight early type stars at DM 11.1 ± 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 m0, and c0 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 Lester, Gray and Kurucz (1986), 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 ± 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 Lester, Gray and Kurucz (1986) and the specified metalicity. We have utilized the (b−y) vs. c0 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 their temperatures with more accuracy, a plot of (b−y) vs. β 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 and Maeder (1993) for open clusters; a log age of 8.266 (1.845 x 10^7 yr) is found from the relation -3.611 log log Teff + 22.956 valid in the range log log Teff within the limits [3.98, 4.25] for NGC 6811; whereas for NGC 6830 the relation log(age) = -3.499 log log Teff + 22.476 valid in the range [4.25, 4.56] yields log (age) of 7.69 (4.89 x 10^7 yr).

These determinations are confirmed by constructing the color-magnitude diagram of NGC 6811 and NGC 6830 which are shown in Figs 4 and 5, respectively. The unreddened magnitudes ([b−y]o,MV) 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
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 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 1024 x 1024 CCD camera with a field of view of 16.5'x16.5' with standard Johnson-Cousin-Bessell filters in B and V bands, of 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 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 and 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 and 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 V10-16) 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 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 W90 as reference and check stars. Although the time span we observed was too short to detect long period variation, the only star which showed clear variation was V4, with two clearly discernible peaks and 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 and belong to a later spectral type which makes them unlikely to be δ 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 determine 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 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 red-
dening (in Nissen’s (1988) work, section 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 \(E(b - y)\) of 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 determined. 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 37 stars belong to a cluster. Since they are the brightest, the conclusions on the age which agrees 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 Hipparcos and Tycho data basis. 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 Becker (1947), Sanders (1971), Lindoff (1972), Barkhatova (1978) and the more recent ones, the compilation by Kharchenko et al. (2005) and the variability study of Luo et al. (2009). 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 in the 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 GlushkKhova et al. (1999) which, from radial velocity measurements for 60 late-type stars and UBVRI photoelectric photometry refined the distance modulus to the cluster to be 10.47 ± 0.08 mag and \(E(B-V)\) of 0.12 ± 0.02, in agreement with the values we derived.

We were able to determine membership in 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 definitively non-member stars. For the rest not much can be said. Accurate temperature determination was done for each one.

NGC 6830. Again, since no previous uvby−β 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, much more data is 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.

We would like to thank the staff of the OAN and E. Romero for their assistance in securing the observations. This work was partially supported by PAPIIT IN110102 and IN114309. HG, ER, SS, AE and ARL thank the IA-UNAM for the opportunity to carry out the observations. JH thanks the hospitality of the UNAN. Typing and proofreading were done by J. Orta, and J. Miller, respectively. C. Guzmán, F. Salas and A. Díaz assisted us in the computing. This research has made use of the Simbad databases operated at CDS, Strasbourg, France and NASA ADS Astronomy Query Form.

REFERENCES

Arellano-Ferro, A. & Parrao, L., 1988 Reporte Técnico 57, IA-UNAM.
Barkhatova K.A., et al. 1978, in Star clusters and binary systems, p. 18
Becker W. 1947, Astr. Nach. 275, 171 - Mitt. Hambourg 8 no 60
Borucki, W.J., et al. 1997, ASP Conf. Ser 119, 153
The Astronomical Almanac, 2006
Crawford D. L. & Mander, J., 1966 AJ 71, 114
Fox Machado, L. et al. 2006, A&A, 446, 611
Fox Machado, L., et al., 2002, A&A, 382, 556
Fox Machado, L., et al., 2001, In: Proceedings of the SOHO 10/GONG 2000 Workshop: Helio- and asteroseismology at the dawn of the millennium, ESA-SP 464, 427
Girardi, L., Bertelli, G., Bressan, A., et al., 2003, Memorie della Società Astronomica Italiana, V. 74, p. 474
Golay, M., 1974 Intro to Astron. Photometry (Dordrecht: Reidl)
Grönbäck, B.; Olsen, E. H. & Strömgren, B. 1976 AAS 26, 155

Kharchenko et al., 2005, A & A, 438, 1163
Lester, J. B., Gray, R. O. & Kurucz, R. I. 1986 ApJ 61, 509
Li, Z.P., et al., 2002, A&A, 395, 873
Li, Z.P., et al., 2004, A&A, 420, 283
Lindoff U. 1972, Astron. Astrophys. 16, 315
Luo, Y. P., Zhang, X. B., Luo, C. Q., Deng, L. C., & Luo, Z. Q., 2009 New Astronomy 14, 584
Meynet, G., Mermilliod, J. C., & Maeder, A., 1993 AAS 98, 477
Netopil, M., et al., 2007, A&A, 462, 591
Nissen, P., 1988 A&A 199, 146
Olsen, E. H., 1983 A&AS 54, 55
Pauzen, E. & Mermilliod, J. C., 2007 WEBDA, A Site Devoted to Stellar Open Clusters
Peña, J.H., et al., 1994, RevMexAA, 28, 139
Peña, J.H., et al., 1998, A&AS, 129, 9
Peña, J.H., et al., 2003, RevMexAA, 39, 131
Peña, J.H., et al., 2007, RevMexAA, 43, 329
Peña, J. H., & Sareyan, J. P., 2006 RevMexAA 42, 179
Rose, M. B., Hintz, E. G., 2007 AJ 134, 2067
Sanders, W. L., 1971 AA 15, 368
Shobbrook, R. R., 1984 MNRAS 211, 659
Van Cauwen, P. Lampens, P., Robertson, C. W., et al., 2005. CoAst 146, 21
### TABLE 2
TRANSFORMATION COEFFICIENTS OBTAINED FOR THE TWO OBSERVED SEASONS

| season | B    | D    | F    | J    | H    | I    | L    |
|--------|------|------|------|------|------|------|------|
| 2009   | -0.005 | 0.975 | 1.002 | 0.037 | 1.008 | -0.067 | -1.397 |
| σ      | 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 |
| σ      | 0.013 | 0.003 | 0.034 | 0.002 | 0.042 | 0.145 | 0.021 |

### TABLE 4
$uvby - \beta$ PHOTOELECTRIC PHOTOMETRY OF THE OPEN CLUSTER NGC 6830

| ID | V   | $(b - y)$ | $m_1$ | $c_1$ | β   | SpTyp | sptp |
|----|-----|-----------|-------|-------|-----|-------|------|
|    |     |           | Phe   | Spec  |     |       |      |
| 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 | B8 V  | 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 | B3 V  |       |
| 2258 | 13.003 | 0.546     | 0.086 | 0.484 | 2.721 | F9 V  |       |
| 2257 | 12.166 | 0.390     | -0.008 | 0.584 | 2.706 | B7 V  |       |
| 26 | 12.309 | 0.564     | 0.160 | 0.255 | 2.661 | G1 V  |       |
| 164 | 12.240 | 0.460     | 0.093 | 0.819 | 2.766 | A8 V  |       |
| 25 | 12.465 | 0.333     | 0.012 | 0.661 | 2.718 | B8 V  |       |
| 24 | 11.644 | 0.391     | -0.034 | 0.612 | 2.635 | B5 V  | B6 V B6 IV |
| 2  | 10.625 | 0.329     | -0.017 | 0.606 | 2.603 | B5 V  |       |
| 3  | 12.888 | 1.620     | 0.383 | 0.256 | 2.569 | K G   |       |
| 39 | 11.192 | 0.386     | -0.051 | 0.681 | 2.668 | B8 I  | B5 IV |
| 2275 | 11.909 | 1.160     | 0.306 | -0.047 | 2.576 | B7 V  |       |
| 13 | 12.787 | 0.767     | 0.134 | 0.380 | 2.605 | K0 V  |       |
| 14 | 11.995 | 0.348     | 0.017 | 0.532 | 2.714 | B6 V  | B6 V B6 IV |
| 15 | 12.659 | 0.407     | -0.035 | 0.646 | 2.681 | B6 V  |       |
| 16 | 12.456 | 0.408     | 0.108 | 0.807 | 2.794 | K     |       |
TABLE 6
REDDENING, UNREDDENED PARAMETERS AND DISTANCE OF 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 |

TABLE 7
COMPILED CHARACTERISTICS FOR NGC 6830 AND NGC6811

| Cluster | Source                  | Log age | Reddening [mag]/E(B-V) | 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           |             |
|         | Ghushkova 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 (Webda)| 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 (Webda)| 8.80 | 0.16                   | 1.22           |             |
|         | PP                      | 8.27    | 0.14                   | 1.64           | -0.02       |
TABLE 3

PHOTOELECTRIC PHOTOMETRY OF THE OPEN CLUSTER NGC 6811

| WBD | V  | (b − y) | m₁ | c₁ | bt   | sV  | sby  | sm₁ | sc₁ | sbt | N  | Spectral Type |
|-----|----|---------|----|----|------|-----|------|-----|-----|-----|----|---------------|
|     |    |         |    |    |      |     |      |     |     |     |    |               |
| 4   | 12.681 | 0.259   | 0.127 | 0.861 | 2.706 |     |      |     |     |     |    | A3V          |
| 5   | 11.795 | 0.168   | 0.185 | 0.950 | 2.770 | 0.067 | 0.028 | 0.015 | 0.029 | 0.062 | 28 | A5V          |
| 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           |
| 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          |
| 18  | 12.118 | 0.236   | 0.144 | 0.966 | 2.806 |     |      |     |     |     | 1 | A5V          |
| 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           |
| 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           |
| 33  | 11.917 | 0.232   | 0.149 | 0.950 | 2.771 |     |      |     |     |     | 1 | A5V          |
| 34  | 11.623 | 0.204   | 0.204 | 0.956 | 2.829 |     |      |     |     |     | 1 | A5p          |
| 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          |
| 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          |
| WBD | V    | $b - y$ | $m_1$ | $c_1$ | bt | sV  | sby | sm$_1$ | sc$_1$ | sbt | N | Spectral Type | Photometry | WBD |
|-----|------|---------|-------|-------|----|-----|-----|--------|-------|-----|---|----------------|-------------|-----|
| 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          |             |     |
| 48  | 14.318 | 0.269  | 0.139 | 0.592 | 2.590 | 0.076 | 0.094 | 0.115 | 0.125 | 0.035 | 2  | F5V          |             |     |
| 51  | 16.361 | 0.178  | 0.191 | 0.898 | 2.774 | 0.076 | 0.020 | 0.030 | 0.045 | 0.085 | 3  | A5V          |             |     |
| 52  | 13.356 | 0.266  | 0.136 | 0.757 | 2.713 | 0.027 | 0.025 | 0.029 | 0.027 | 0.078 | 3  | A8V          |             |     |
| 53  | 12.160 | 0.247  | 0.149 | 0.787 | 2.691 | 0.013 | 0.025 | 0.024 | 0.055 | 0.037 | 2  | A8V          |             |     |
| 55  | 14.039 | 0.439  | 0.161 | 0.357 | 2.670 | 0.196 | 0.114 | 0.161 | 0.256 | 0.132 | 3  | K0V          |             |     |
| 56  | 14.350 | 0.622  | 0.219 | 0.151 | 2.650 | 0.187 | 0.231 | 0.122 | 0.256 | 0.132 | 3  | K0V          |             |     |
| 57  | 12.846 | 0.224  | 0.163 | 0.728 | 2.714 |       |       |       |       |       | 2  | A8V          |             |     |
| 58  | 15.234 | 0.979  | 0.846 | 0.714 | 0.193 | 0.569 | 0.401 | 0.677 | 0.294 |       | 2  | >G           |             |     |
| 59  | 13.609 | 0.352  | 0.088 | 0.557 | 2.897 | 0.041 | 0.016 | 0.056 | 0.021 | 0.366 | 2  | F2V          |             |     |
| 60  | 14.450 | 0.460  | 0.199 | 0.217 | 2.510 | 0.087 | 0.164 | 0.106 | 0.057 | 0.103 | 2  | G2V          |             |     |
| 61  | 10.850 | 0.272  | 0.152 | 0.869 | 2.737 |       |       |       |       |       | 1  | A8V          |             | A2 |
| 62  | 10.925 | 0.298  | 0.139 | 0.876 | 2.713 |       |       |       |       |       | 1  | A5V          |             | A4 |
| 63  | 13.716 | 0.388  | 0.154 | 0.473 | 2.551 |       |       |       |       |       | 1  | G0V          |             | A2 |
| 64  | 9.851  | 0.992  | 0.830 | 0.166 | 2.551 |       |       |       |       |       | 1  | >G           |             | K5 |
| 65  | 12.322 | 0.415  | 0.171 | 0.305 | 2.568 | 0.078 | 0.007 | 0.003 | 0.028 | 0.008 | 2  | G0V          |             |     |
| 66  | 13.860 | 0.257  | 0.206 | 0.461 | 2.650 | 0.120 | 0.040 | 0.041 | 0.028 | 0.025 | 2  | G0V          |             |     |
| 67  | 13.664 | 0.270  | 0.167 | 0.567 | 2.676 | 0.070 | 0.023 | 0.011 | 0.040 | 0.037 | 2  | F7V          |             |     |
| 68  | 10.393 | 0.935  | 0.719 | 0.146 | 2.519 |       |       |       |       |       | 1  | >G           |             |     |
| 69  | 13.025 | 0.705  | 0.341 | 0.333 | 2.546 |       |       |       |       |       | 1  | >G           |             |     |
| 70  | 12.860 | 0.308  | 0.134 | 0.545 | 2.684 |       |       |       |       |       | 1  | F5V          |             |     |
| 71  | 13.389 | 0.334  | 0.106 | 0.490 | 2.662 |       |       |       |       |       | 1  | F2V          |             |     |
| 72  | 12.622 | 0.380  | 0.206 | 0.399 | 2.617 |       |       |       |       |       | 1  | G2V          |             |     |
| 73  | 12.260 | 0.221  | 0.166 | 0.722 | 2.704 |       |       |       |       |       | 1  | A8V          |             |     |
| 74  | 11.962 | 0.168  | 0.184 | 0.957 | 2.817 | 0.036 | 0.036 | 0.028 | 0.028 | 0.078 | 2  | A5V          |             | B9 |
| 75  | 10.682 | 0.671  | 0.393 | 0.333 | 2.569 |       |       |       |       |       | 1  | >G           |             |     |
### TABLE 3 (CONTINUED)

| WBD | V   | $(b-y)$ | $m_1$ | $c_1$ | bt  | sV | sby | sm$_1$ | sc$_1$ | sst | N  | Spectral Type |
|-----|-----|---------|-------|-------|-----|----|-----|--------|--------|-----|----|---------------|
| 102 | 12.882 | 0.586  | 0.221 | 0.287 | 2.562 |    |     |        |        |     |    | K0V           |
| 105 | 12.419 | 0.230  | 0.241 | 0.850 | 2.802 |    |     |        |        |     |    | Ap            |
| 106 | 11.379 | 0.301  | 0.138 | 0.796 | 2.713 |    |     |        |        |     |    | A8V A3        |
| 107 | 12.726 | 0.419  | 0.123 | 0.414 | 2.640 |    |     |        |        |     |    | F7V           |
| 112 | 12.825 | 0.372  | 0.146 | 0.412 | 2.663 |    |     |        |        |     |    | F9V           |
| 113 | 11.471 | 0.233  | 0.144 | 0.990 | 2.767 |    |     |        |        |     |    | 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 |    |     |        |        |     |    | G2V           |
| 122 | 12.825 | 0.372  | 0.146 | 0.412 | 2.663 |    |     |        |        |     |    | F9V           |
| 123 | 13.970 | 0.648  | 0.689 | 0.386 | 2.579 |    |     |        |        |     |    | >G            |
| 133 | 12.069 | 0.576  | 0.346 | 0.230 | 2.510 |    |     |        |        |     |    | >G G2        |
| 139 | 13.197 | 0.358  | 0.082 | 0.569 | 2.646 |    |     |        |        |     |    | F2V           |
| 146 | 12.504 | 0.353  | 0.151 | 0.475 | 2.650 |    |     |        |        |     |    | F9V           |
| 147 | 12.129 | 0.168  | 0.200 | 0.972 | 2.847 |    |     |        |        |     |    | A5V A4        |
| 178 | 9.909  | 1.039  | 0.839 | 0.225 | 2.835 |    |     |        |        |     |    | >G            |
| 218 | 12.087 | 0.194  | 0.157 | 0.982 | 2.858 |    |     |        |        |     |    | A5V A5        |
| 489 | 11.000 | 0.252  | 0.179 | 0.855 | 2.748 |    |     |        |        |     |    | A5V           |
| 491 | 13.681 | 0.240  | 0.241 | 0.857 | 2.889 |    |     |        |        |     |    | Ap            |
| V17 | 15.009 | 0.560  | 0.067 | 0.157 | 2.468 |    |     |        |        |     |    | F9V           |
| 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    |
### TABLE 5 (CONTINUED)

| ID  | $E(b-y)$ | $(b-y)_0$ | $m_0$ | $c_0$ | $\beta$ | $V_0$ | $M_V$ | DM  | DST | [Fe/H] | Memb |
|-----|----------|-----------|-------|-------|---------|-------|-------|-----|-----|--------|------|
| 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  |
| WBD | Luo | Sanders | Becker | Barkhatova | Kharchenko | Prob Sanders | Pkin | Pph | Psp | mbr  |
|-----|-----|---------|--------|------------|------------|--------------|------|-----|-----|------|
| 112 | 177 | 51      | 1136   | 0          | m          | m            |      |     |     |      |
| 122 |     |         |        |            |            |              |      |     |     |      |
| 107 | 183 | 48      |        |            |            | 96           |      |     |     |      |
| 31  | 102 | 15      | 1057   | 97         | m          |              |      |     |     |      |
| 489 | 6   | 205     | 2080   | 89         | m          |              |      |     |     |      |
| 146 | 187 | 42      | 1143   | 0          | m          |              |      |     |     |      |
| 68  | 110 | 86      | 1065   | 78         | 0.9272     | 1            | 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     | 1104   | 96         | m          |              |      |     |     |      |
| 147 | 189 | 43      | 1146   | 97         | m          |              |      |     |     |      |
| 70  | 3   | 108     | 1063   | 76         | 0.9837     | 1            | 1    | 1   | m   |      |
| 86  | 98  | 5       | 1050   | 89         | m          |              |      |     |     |      |
| 26  | 86  | 10      | 1038   | 69         | 0.4193     | 1            | 1    | 1   | m   |      |
| 99  | 159 | 29      | 1122   | 97         | m          |              |      |     |     |      |
| 18  | 1   | 97      | 1049   | 73         | 0.0016     | 1            | 1    | 1   | m   |      |
| 115 | 149 | 65      |        | 95         | m          |              |      |     |     |      |
| 16  | 103 | 81      | 1059   | 90         | m          |              |      |     |     |      |
| 54  | 147 | 68      | 1114   | 97         | m          |              |      |     |     |      |
| 113 | 5   | 166     | 1126   | 98         | 0.8128     | 1            | 1    | 1   | m   |      |
| 92  | 115 | 20      | 1071   | 0          | m          |              |      |     |     |      |
| 46  | 160 | 36      | 1124   | 96         | m          |              |      |     |     |      |
| 33  | 13  | 113     | 1066   | 79         | 0.9765     | 0.9971       | 1    | 1   | m   |      |
| 114 | 146 | 66      |        | 96         | m          |              |      |     |     |      |
| 49  | 165 | 46      | 1125   | 97         | 0.7504     | 1            | 1    | 1   | m   |      |
| WBD | Luo | Sanders | Becker | Barkhatova | Kharchenko | Prob Sanders | Pkin | Pph | Psp | mbr |
|-----|-----|---------|--------|------------|------------|--------------|------|-----|-----|-----|
| 5   | 127 | 25      | 1092   | 83         | 93         | 0.9227       | 0.7357| 1   | m   |
| 9   | 16  | 134     | 71     | 1101       | 86         | 0.9565       | 1     | 1   | m   |
| 62  | 123 | 77      | 1087   | 97         |            |              |       |     |     |     |
| 139 | 131 |         | 1096   | 95         |            |              |       |     |     |     |
| 44  | 11  | 157     | 33     | 1120       | 95         | 0.9137       | 1     | 1   | m   |
| 53  | 10  | 135     | 69     | 1105       | 94         |              |       |     |     | m   |
| 45  |     | 155     | 34     | 1118       | 94         | 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         | 0.8117       | 0.97  | 1   | 1   | und |
| 32  |     | 106     | 16     | 1061       | 97         |              |       |     |     | und |
| 35  |     | 128     |        | 1095       | 80         |              |       |     |     | und |
| 38  |     | 150     | 27     | 1115       | 0          |              |       |     |     | und |
| WBD | Luo | Sanders | Becker | Barkhatova | Kharchenko | Prob Sanders | Pkin | Pph | Psp | mbr |
|-----|-----|---------|--------|------------|-------------|--------------|------|-----|-----|-----|
| 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         |
| 118 | 145 | 64      | 1113   | 0          | und         |
| 123 |     |         |        |            | 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         |