Galactic model parameters for field giants separated from field dwarfs by their 2MASS and V apparent magnitudes

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Abstract. We present a procedure which separates field dwarfs and field giants by their 2MASS and V apparent magnitudes. The procedure is based on the spectroscopically selected standards, hence it is confident. We applied this procedure to stars in two fields, SA 54 and SA 82, and we estimated a full set of Galactic model parameters for giants including their total local space density. Our results are in agreement with the ones appeared recently in the literature.

Key words: Galaxy: structure – Galaxy: fundamental parameters – Stars: giants

1. Introduction

For some years, there has been a conflict among the researchers about the history of our Galaxy. Yet there has been a large improvement about this topic since the pioneering work of Eggen, Lynden-Bell & Sandage (1962) who argued that the Galaxy collapsed in a free-fall time ($\sim 2 \times 10^8$ yr). Now, we know that the Galaxy collapsed over many Gyr (e.g. Yoshii & Saio 1979; Norris, Bessell & Pickles 1985; Norris 1986; Sandage & Fouts 1987; Carney, Latham & Laird 1990; Norris & Ryan 1991; Beers & Sommer-Larsen 1995) and at least some of its components are formed from the merger or accretion of numerous fragments, such as dwarf-type galaxies (cf. Searle & Zinn 1978; Freeman & Band-Hawthorn 2002, and references therein). Also the number of population components increased from two to three, complicating interpretations of any data set. The new component (the thick disc) was introduced by Gilmore & Reid (1983) in order to explain the observation that star counts towards the South Galactic Pole were not in agreement with a single-disc (thin disc) component, but rather could be much better represented by two such components. The new component is discussed by Gilmore & Wyse (1985) and Wyse & Gilmore (1986).

The researchers use different methods to determine the parameters for three population components and try to interpret them in relation to the formation and evolution of the Galaxy. Among the parameters, the local density and the scaleheight of the thick disc are the ones for which the numerical values improved relative to the original ones claimed by Gilmore & Reid (1983). In fact, the researchers indicate a tendency for the original local density of the thick disc to increase from 2 to 10 per cent relative to the local density and for its scaleheight to decrease from the original value of 1.45 kpc down to 0.65 kpc (Chen et al. 2001). In some studies, the range of values for the parameters is large, especially for the thick disc. For example, Chen et al. (2001) and Siegel et al. (2002) give 6.5-13 and 6-10 per cent, respectively, for the relative local density for the thick disc. We showed that the model parameters are absolute magnitude dependent, and that such a process limits the range of the parameters considerably (Karaali, Bilir & Hamzaoglου, 2004a).

The studies related to the Galactic structure are usually carried out by star counts. However, it is stated by many authors (cf. Siegel et al., 2002) that the non-invertibility and the vagaries of solving the non-unique convolution by trial and error limit the star counts and will be a weak tool for exploring the Galaxy. Direct comparison between the theoretical and observed space densities is another method used. In the literature, there is limited number of research based on this method. The works of Basle group (del Rio & Fenkart 1987; Fenkart & Karaali 1987) and the recent work of Phleps et al. (2000), Siegel et al. (2002), Karaali et al. (2003), Du et al. (2003), Karaali et al. (2004a) and Bilir, Karaali & Gilmore (2005a) can be given as examples of this research.

In many studies, the Galactic model parameters are estimated without any discrimination between dwarf and giants, whereas some researchers estimated model parameters for different star categories (e.g. Pritchet 1983, Bahcall & Soneira 1984, Buser & Kaeser 1985 and Mendez & Altena 1996). A very recent work is devoted only to estimation of the model parameters for giants (Cabrera-Lavers, Garzon & Hammersley 2005). Separation of field giants and dwarfs plays an important role in the Galactic model estimation. The
most efficient method for separation of stars into these categories is of course spectroscopical one. It can be done either by inspection of their spectral lines or using their surface gravities. However, both procedures are rather tiring. An easier procedure is to separate dwarfs and evolved stars (subgiant or giants) such as to obtain a luminosity function consistent with the local luminosity function of nearby stars due to Gliese & Jahreiss (1991) and Jahreiss & Wielen (1997). The procedure of this separation is based on the fact that the local luminosity functions obtained for many fields indicated a systematic excess of star counts relative to the luminosity function of nearby stars for the fainter segment, i.e. dwarf and giant, by us according to their surface gravities. Thus, stars with \( \log g \leq 3 \) were classified as giants, whereas those with \( \log g \geq 4 \) were assumed to be dwarfs. The catalog of Ratnatunga & Freeman (1989) from the other hand, offers 101 giants classified spectroscopically. The apparent limiting magnitude for stars in this catalog is \( V = 16 \). Thus, we have a sample of 453 stars separated into 196 dwarfs and 257 giants confidently.

Our aim is to compare the 2MASS apparent magnitudes, \( J, H \) and \( K \), with the \( V \) apparent magnitude, from which we expect a systematic deviation between the two stellar categories in the two magnitude plane. The 2MASS (Skrutskie et al. 1997) is using two 1.3m telescopes, one on Mt. Hopkins in Arizona and one at the Cerro Tololo Inter-American Observatory in Chile, to survey the entire sky in near-infrared light\(^1\). In addition providing a context for the interpretation of results obtained at infrared and other wavelengths, 2MASS will provide direct answers to immediate questions on the large-scale structure of the Milky Way and the Local Universe. We used the 2MASS All-Sky Catalog of Point Sources of Cutri et al. (2003) to draw the \( J, H \) and \( K \) magnitudes for 453 stars mentioned above as well as their \( V \) magnitudes. The data are given in Table 1. Fig. 1a-c compares the 2MASS magnitudes and the \( V \) magnitude for the sample stars where a systematic deviation between giants and dwarfs is conspicuous, especially at the faint magnitudes. We adopted the straight line defined by positions of two giants as the upper envelope of giants (hence lower envelope of dwarfs). The first position corresponds to the giant faintest in two magnitudes, whereas the other one is the giant brightest in \( V \) but faintest in the 2MASS magnitude. The equation for three lines in Fig. 1a-c are given in the following:

\[
J = 0.957V - 1.079 \tag{1}
\]
\[
H = 0.931V - 1.240 \tag{2}
\]
\[
K = 0.927V - 1.292 \tag{3}
\]

\(^1\) http://www.ipac.caltech.edu/2mass/overview/about2mass.html

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**Fig. 1.** \( V \) and 2MASS magnitudes of the Cayrel et al. (2001) and Ratnatunga & Freeman (1989) in our sample. (a) \( J/V \), (b) \( H/V \) and (c) \( K/V \). The symbols (+) and (●) correspond to dwarfs and giants, respectively.
Fig. 2. Two magnitude diagrams for stars in two fields: (a), (b) and (c) for SA 54; (d), (e) and (f) for SA 82. The solid line is adopted from Fig. 1.

Table 2. Data for the fields SA 54 and SA 82. The symbols give: \( N_s \): number of sources, \( N_{glx} \): number of galaxies, \( N_d \): number of dwarfs and \( N_g \): number of giants.

| Field | l (°)  | b (°)  | Size (deg^2) | \( N_s \) | \( N_{glx} \) | \( N_d \) | \( N_g \) |
|-------|--------|--------|--------------|----------|--------------|----------|----------|
| SA 54 | 200.1  | 58.8   | 2.56         | 1334     | 66           | 1168     | 100      |
| SA 82 | 6.3    | 66.3   | 1.20         | 909      | 79           | 747      | 83       |

3. Application of the procedure to the giants in two star fields

We applied the procedure cited above to separate the giants and dwarfs in two high latitude fields, SA 54 and SA 82, investigated by Basle astronomers (Becker et al. 1982, 1991) in the UBV photometry. Data for the fields are given in Table 2. We excluded the extragalactic objects via the procedure of Bilir, Karataş & Ak (2003), then \( J/V \), \( H/V \), and \( K/V \) two magnitude diagrams were drawn for stars in each field (Fig. 2). The distribution of stars about a central line with small deviations is a strong evidence for the matching procedure between spectroscopic catalogues and 2MASS catalogue. Although all the 2MASS magnitudes are available for dwarf-giant separation we preferred the \( J \) magnitude. The limiting apparent magnitude is \( V = 18 \) for both fields, however we restricted our work with \( V = 16 \), where the procedure in Section 2 is defined. The number of giants in SA 54 and SA 82 turned out to be 100 and 83, respectively. They are plotted in Fig. 3 and their metal abundances, necessary for absolute magnitude determination, are evaluated by means of iso-metallicity lines of Lejuene, Cuisinier and Buser (1997) which are available for \( \log g = 3 \) and cover an interval of \(-3 \leq [Fe/H] \leq +1 \) dex. The absolute magnitudes of 183 giants in two fields are determined by the following equations of Ratnatunga & Freeman (1989):

\[
M(V) = A_0 + 1.11[Fe/H] + 0.443 \tag{4}
\]

\[
A_0 = 68.08 + 170.3C + 163.4C^2 - 71.20C^3 + 11.75C^4 \tag{5}
\]

\[
C = \min\{(B - V)_0 - 0.10[Fe/H] - 0.013, 1.80\} \tag{6}
\]

Fig. 3. \((U - B, B - V)\) two-colour diagrams for two fields. (a) for SA 54 and (b) for SA 82. The iso-metallicity lines are taken from Lejuene et al. (1997).
Table 3. The logarithmic space density function $D^* = \log D + 10$ for giants in SA 54. $z^*$ is the mean distance from the Galactic plane and a figure in the bracket, in the column of volume, show that the value at the left of it will be multiplied by ten to the power of this figure. The other symbols are explained in the text (distances in kpc, volumes in pc$^3$).

| $r_1 - r_2$ | $\Delta V_{1.2}$ | N  | $z^*$ | $D^*$ |
|-------------|------------------|----|-------|-------|
| 0 - 1       | 2.60 (05)        | 24 | 0.52  | 5.97  |
| 1 - 2       | 1.82 (06)        | 17 | 1.34  | 4.97  |
| 2 - 5       | 3.04 (07)        | 13 | 2.86  | 3.63  |
| 5 - 10      | 2.27 (08)        | 14 | 6.14  | 2.79  |
| 10-15       | 6.17 (08)        | 8  | 10.78 | 2.11  |
| 15-25       | 3.18 (09)        | 10 | 18.18 | 1.50  |
| 25-40       | 1.26 (10)        | 9  | 27.03 | 0.85  |
| 40-54       | 2.43 (10)        | 5  | 43.78 | 0.31  |

Table 4. The logarithmic space density function $D^* = \log D + 10$ for giants in SA 82 (symbols as in Table 3).

| $r_1 - r_2$ | $\Delta V_{1.2}$ | N  | $z^*$ | $D^*$ |
|-------------|------------------|----|-------|-------|
| 0 - 1       | 1.22 (05)        | 7  | 0.56  | 5.76  |
| 1 - 2       | 8.53 (05)        | 10 | 1.15  | 5.07  |
| 2 - 5       | 1.43 (07)        | 16 | 3.04  | 4.05  |
| 5 - 7.5     | 3.62 (07)        | 9  | 5.56  | 3.40  |
| 7.5-15      | 3.60 (08)        | 9  | 11.47 | 2.40  |
| 15-25       | 1.49 (09)        | 9  | 18.28 | 1.78  |
| 25-40       | 1.85 (10)        | 6  | 45.47 | 0.51  |
| 40-60       | 6.25 (10)        | 9  | 70.31 | 0.16  |

The distance to a star relative to the Sun is carried out by the following formula:

$$[V - M(V)]_0 = 5 \log r - 5$$  \hspace{1cm} (7)

Then, the vertical distance to the Galactic plane ($z$) of a star could be evaluated by its distance $r$ and its Galactic latitude ($b$) which could be provided by its right ascension and declination.

Table 3 and Table 4 give the logarithmic space density functions, $D^* = \log D + 10$, for SA 54 and SA 82 respectively, where $D = N/\Delta V_{1.2}$; $\Delta V_{1.2} = (\pi/180)^2(\Sigma/3)(r_2^3 - r_1^3)$; $\Sigma$ denotes the size of the field; $r_1$ and $r_2$ denote the limiting distance of the volume $\Delta V_{1.2}$; and $N$ denotes the number of stars.

4. Galactic model parameters

The comparison of the observed space density functions given in Tables 3 and 4 and the density law combined for three populations, i.e. thin disc, thick disc and halo is carried out in Fig. 4, by $\chi^2$ method. The density laws for three populations are not given here, however one can find them in many papers (cf. Karaali et al. 2004a). The resultant Galactic model parameters for three populations and the total local logarithmic space density for giants, for two fields, are given in Table 5. The most conspicuous numerical values are for the total local densities for giants in two fields, i.e. $n^* = 6.68$ and $n^* = 6.62$ for SA 54 and SA 82, respectively, which are rather close to the one of Gliese (1969), i.e. $\odot = 6.64$.

5. Conclusion

We presented a different procedure for separation of field dwarfs and field giants by comparison of their 2MASS and V magnitudes down to the limiting magnitude of $V = 16$. The procedure is based on the spectroscopically selected standards, hence it is confident. We applied this procedure to stars in two fields, SA 54 and SA 82, and we estimated the Galactic model parameters for thin disc, thick disc and halo giants as well as their total local space density (Table 5).

Our results are in agreement with the ones appeared in the literature so far, however the model parameters estimated by many researchers are restricted to only scaleheight of discs. Whereas in this work, we give a full set of model parameters...
for three populations, thin disc, thick disc and halo. The pioneer works give rough scaleheights for discs (thin and thick discs), and claim for the existence of halo giants. For example, Pritchet (1983), Bahcall & Soneira (1984) and Buser & Kaeser (1985) give 150-250 pc, 250±100 pc, and less than 300 pc for disc scaleheight, respectively. Mendez & van Altena (1996) give more precise values, i.e. a mean scaleheight of 250±32 pc for disc subgiants and they claim that it is in agreement with previous scaleheight for red giants. The most recent scaleheights for thin and thick disc giants given by Cabrera-Lavers et al. (2005) are in agreement with the ones estimated in our work for SA 82 giants. Actually, they give 268.81±12.65 pc and 1061.9±52.16 pc, for thin and thick disc giants which are close to 259 pc and 927 pc given in Table 5. The agreement of the (total) local logarithmic space densities estimated for giants in two fields, $D^{*}(0) = 6.68$ and $D^{*}(0) = 6.62$ for SA 54 and SA 82 respectively, with the ones of Gliese (1969), $\chi = 6.64$, is a strong confirmation both for the Galactic model parameters for giants and for the procedure used for separation of field dwarfs and field giants.

These new calibrations and procedure having been adapted into robotic telescopes, i.e. ROTSE I-III, can be applied efficiently in separation of the dwarfs and giants stars in the star fields. The giant candidates selected through this procedure can be used in giant stars survey as in Grid Giant Star Survey (Bizyaev et al. 2005). Also we applied this method to NGC 1513 open cluster using ROTSE-IIId (Akerlof et al. 2003) telescope located in Bakırlıtepe Antalya, and we could separate the dwarfs and giants easily. Hence, we can say that this procedure would be used as a practical tool in separation of giants and dwarfs in the sky surveys carried out by robotic telescope in red bands.

Finally, we should emphasize that there are systematic differences between the model parameters for giants in two fields which are investigated homogeneously. Although the galactic latitudes of these fields are close to each other, $b = +58^{o}.8$ and $b = +66^{o}.3$ for SA 54 and SA 82, respectively, their galactic longitudes are quite different, $l = 200^{o}.1$ and $l = 6^{o}.3$ for the fields in the same order. Hence, it seems that the systematic differences between the model parameters for giants in two fields originate from their difference in longitude which confirms our suggestion that Galactic model parameters are Galactic longitude dependent (Bilir et al. 2005b).

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### Table 5. Galactic model parameters, for two fields, for three populations, i.e. thin disc, thick disc, and halo, resulting from the comparison of observed and combined space densities with the density law combined for the thin and thick discs, and halo. The symbols: $n^{*}$: the logarithmic local space density, $H$: the scaleheight, $\kappa$: the axes ratio for halo, $n_{tot}^{*}$: the combined logarithmic local space density for three populations, $\chi^2$: the statistics used for comparison the observed data with the density law.

| Field | Thin disc | Thick disc | Halo |
|-------|-----------|------------|------|
|       | $n^{*}$   | $H$ (pc)   | $n^{*}$ | $H$ (pc) | $n^{*}$ | $\kappa$ | $n_{tot}^{*}$ | $\chi^2 (10^{-10})$ |
| SA 54 | 6.64±0.01 | 301±13 | 5.58±0.03 | 583±22 | 3.60±0.12 | 0.74±0.06 | 6.68 | 178 |
| SA 82 | 6.60±0.01 | 259±14 | 5.34±0.03 | 927±39 | 3.61±0.10 | 0.74±0.07 | 6.62 | 341 |

### References

- Ak, S.G., Karaali, S., Buser, R.: 1998, A&AS, 131, 345
- Akerlof, C.W., et al.: 2003, PASP, 115, 132
- Bahcall, J.N., Soneira, R.M.: 1984, ApJS, 55, 67
- Becker, W., Morales-Duran, C., Ebner, E., Esin-Yilmaz, F., Fenkart, R., Hartl, H., Spaenhauer, A.: 1982, Photometric Catalogue for Stars in Selected Areas and other Fields in the RGU-UBV Systems (VIII), Pub. Basel Astronomical Institute.
- Becker, W., Fenkart, R.P., Del Rio, G., Esin-Yilmaz, F., Gülecen, H., Karaali, S., Topaktaş, L.: 1991, Photometric Catalogue for Stars in Selected Areas and other Fields in the RGU-UBV Systems (XIII), Pub. Basel Astronomical Institute.
- Beers, T.C., Sommer-Larsen, J.: 1995, ApJS, 96, 175
- Bilir, S., Karaali, S., Ak, S.G.: 2003, TJP, 27, 235
- Bilir, S., Karaali, S., Buser, R.: 2004, TJP, 28, 289
- Bilir, S., Karaali, S., Gilmore, G.: 2005a, MNARS (submitted)
- Bilir, S., Karaali, S., Ak, S.G., Karaatay, Y., Yaz, E.: 2005b, (in preparation)
- Bizyaev, D., Smith, V.V., Arenas, J., Geisler, D.: 2005, astro-ph/0502369
- Buser, R., Kaeser, U.: 1985, A&A, 145, 1
- Cabrera-Lavers, A., Garzon, F., Hammersley, P.L.: 2005, A&AA, 433, 173
- Carney, B.W., Latham, D.W., Laird, J.B.: 1991, AJ, 99, 572
- Cayrel de Strobel, G., Soubiran, C., Raile, N.: 2001, A&AA, 373, 159
- Chen, B. et al.: 2001, ApJ, 553, 184
- Cutri, R.M., et al.: 2003, VizieR On-line Data Catalog: II/246. Originally published in: University of Massachusetts and Infrared Processing and Analysis Center.
- Del Rio, G., Fenkart, R.P.: 1987, A&AS 68, 397
- Du, C., Zhou, X., Ma, J., Bing-Chih, A., Yang, Y., Li, J., Wu, H., Jiang, Z., Chen, J.: 2003, A&AA, 407, 541
- Eggen, O.J., Lynden-Bell, D., Sandage, A.R.: 1962, ApJ, 136, 748
- Fenkart, R.P., Karaali, S.: 1987, A&AS, 69, 33
- Freeman, K. Bland-Hawthorn, J.: 2002, ARA&A, 40, 487
- Gilmore, G., Reid, N.: 1983, MNRAS, 202, 1025
- Gilmore, G., Wyse, R.F.G.: 1985, AJ, 90, 2015
- Gliese, W.: 1969, Veröff. Astron. Rechen-Institut Heidelberg, No:22
- Gliese, W., Jahreiss, H.: 1991, Preliminary Version of the Third Catalogue of Nearby Stars, Astronom. Rechen-Institut, Heidelberg
- Jahreiss, H., Wielen, R.: 1997, EsASP 402, 675, eds. Battrick, B., Perryman, M.A.C., & Bernacca, P.L. 


Karaali, S.: 1992, VIII. Nat. Astron. Symp. Eds. Z. Aslan and O. Gölbâşı, Ankara-Turkey, p.202
Karaali, S., Ak, S.G., Bilir, S., Karataş, Y., Gilmore, G.: 2003, MN-RAS, 343, 1013
Karaali, S., Bilir, S., Hamzaoğlu E.: 2004, MNRAS, 355, 307
Karaali, S., Bilir, S., Buser, R.: 2004b, PASA, 21, 275
Karataş, Y., Karaali, S., Buser, R.: 2001, A&A, 373, 895
Karataş, Y., Bilir, S., Karaali, S., Ak, S.G.: 2004, AN, 325, 726
Lejeune, Th., Cuisinier, F., Buser, R.: 1997, A&AS, 125, 229
Mendez, R.A., van Altena, W.F.: 1996, AJ, 112, 655
Norris, J.E., Bessell, M.S., Pickles, A.J.: 1985, ApJS, 58, 463
Norris, J.E., 1986: ApJS, 61, 667
Norris, J.E., Ryan, S.G.: 1991, ApJ, 380, 403
Phleps, S., Meisenheimer, K., Fuchs, B., Wolf, C.: 2000, A&A, 356, 108
Pritchet, C.: 1983, AJ, 88, 1476
Ratnatunga, K.U., Freeman, K.C.: 1989, ApJ, 339, 126
Sandage, A., Fouts, G.: 1987, AJ, 93, 74
Searle, L., Zinn, R.: 1978, ApJ, 225, 357
Siegel, M.H., Majewski, S.R., Reid, I.N., Thompson, I.B.: 2002, ApJ, 578, 151
Skrutskie, M.F., et al. 1997, The Impact of Large-Scale Near-IR Sky Surveys, ed. F. N. Epchttein, A. Omont, B. Burton, & P. Persei Garzon, (Dordrecht: Kluwer), 25
Wyse, R.F.G., Gilmore, G.: 1986, AJ, 91, 855
Yoshii, Y., Saio, H.: 1979, PASJ, 31, 339
| Star  | (h, m, s) | V     | J     | H     | K     | type | refs |
|-------|-----------|--------|-------|-------|-------|------|------|
| HD 00097 | 00 05 46  | 9.62   | 8.057 | 0.019 | 7.612 | 0.014 | 7.513 | 0.025 |
| BPS CS 22876-0032 | 00 07 57  | 13.20  | 11.802 | 0.022 | 11.555 | 0.024 | 11.485 | 0.021 |
| HD 00097 | 00 13 53  | 7.44   | 7.406 | 0.021 | 7.087 | 0.029 | 6.962 | 0.023 |
| CS 22876-0032 | 00 14 17  | 8.147  | 0.021 | 7.786 | 0.024 | 7.653 | 0.021 |
| BPS CS 22917-0015 | 00 26 09  | 8.267  | 7.307 | 0.022 | 6.943 | 0.034 | 6.820 | 0.026 |
| HD 00097 | 00 33 14  | 9.54   | 7.181 | 0.018 | 6.605 | 0.034 | 6.417 | 0.017 |
| HD 00097 | 00 36 04  | 9.51   | 7.634 | 0.023 | 7.155 | 0.044 | 6.916 | 0.024 |
| HD 00097 | 00 38 52  | 8.18   | 7.218 | 0.029 | 6.795 | 0.034 | 6.549 | 0.026 |
| BPS CS 22947-0034 | 00 45 40  | 5.73   | 4.975 | 0.026 | 4.697 | 0.049 | 4.598 | 0.024 |
| HD 00097 | 00 51 20  | 7.42   | 6.804 | 0.021 | 6.556 | 0.024 | 6.440 | 0.025 |
| HD 00097 | 00 54 12  | 7.40   | 6.827 | 0.024 | 6.527 | 0.027 | 6.420 | 0.025 |
| HD 00097 | 00 55 43  | 7.46   | 6.864 | 0.027 | 6.564 | 0.029 | 6.456 | 0.027 |
| HD 00097 | 01 00 52  | 7.48   | 6.918 | 0.029 | 6.612 | 0.031 | 6.504 | 0.028 |
| HD 00097 | 01 06 52  | 7.51   | 6.970 | 0.031 | 6.662 | 0.033 | 6.554 | 0.029 |
| HD 00097 | 01 11 01  | 7.53   | 6.988 | 0.033 | 6.690 | 0.034 | 6.582 | 0.030 |
| HD 00097 | 01 16 16  | 7.56   | 7.009 | 0.035 | 6.702 | 0.037 | 6.594 | 0.031 |
| HD 00097 | 01 21 21  | 7.59   | 7.031 | 0.037 | 6.714 | 0.039 | 6.606 | 0.032 |
| HD 00097 | 01 26 26  | 7.62   | 7.053 | 0.039 | 6.727 | 0.041 | 6.619 | 0.033 |
| HD 00097 | 01 31 31  | 7.65   | 7.076 | 0.041 | 6.740 | 0.043 | 6.632 | 0.034 |
| HD 00097 | 01 36 36  | 7.68   | 7.100 | 0.043 | 6.754 | 0.045 | 6.647 | 0.035 |
| HD 00097 | 01 41 41  | 7.71   | 7.124 | 0.045 | 6.768 | 0.047 | 6.660 | 0.036 |
| HD 00097 | 01 46 46  | 7.74   | 7.148 | 0.047 | 6.782 | 0.049 | 6.673 | 0.037 |
| HD 00097 | 01 51 51  | 7.77   | 7.172 | 0.049 | 6.796 | 0.051 | 6.685 | 0.038 |
| HD 00097 | 01 56 56  | 7.80   | 7.196 | 0.051 | 6.810 | 0.053 | 6.697 | 0.040 |

Table 1. V and 2MASS magnitudes of Cayrel et al. (2001) and Ratrnagata & Freeman (1989) for stars in our sample. The coordinates are for the in epoch 2000. Symbols: (g) and (d): giant and dwarf respectively; (1) and (2) correspond to the references of Cayrel et al., 2001, and Ratrnagata & Freeman, 1989, respectively.
| Star       | m (m/s) | e (m/s) | l (m/s) | (". s") | (". s") | (". s") |
|-----------|---------|---------|---------|---------|---------|---------|
| HD 005152 | 0.015   | 22.10   | 4.01    | 6.381   | 0.033   | 22.38   |
| HD 006048 | 0.003   | 22.43   | 1.96    | 6.868   | 0.033   | 22.38   |
| 8            |         |         |         | 1.96    | 6.868   | 0.212   |
| BD +6 +02  | 0.001   | 22.43   | 1.96    | 6.868   | 0.033   | 22.38   |
| HD 006048 | 0.003   | 22.43   | 1.96    | 6.868   | 0.033   | 22.38   |
| 8            |         |         |         | 1.96    | 6.868   | 0.212   |
| Starfield | l (deg) | b (deg) | T (K) | log(g) | log(L/L☉) | [Fe/H] | d (pc) | References |
|----------|--------|--------|-------|--------|-----------|--------|--------|------------|
| SA 127 | 12 41 16.74 | +31 02.79 | 30000 | -4.58 | -4.50 | +0.25 | 0.025 | 2 |
| SA 127 | 11 53 16.88 | -28 17.30 | 28500 | -4.25 | -4.50 | +0.25 | 0.025 | 2 |
| HD 07916 | 11 53 16.88 | -28 17.30 | 28500 | -4.25 | -4.50 | +0.25 | 0.025 | 2 |
| HD 07916 | 11 48 07.79 | -28 17.30 | 28500 | -4.25 | -4.50 | +0.25 | 0.025 | 2 |
| SA 127 | 11 49 07.26 | -31 03.89 | 28500 | -4.25 | -4.50 | +0.25 | 0.025 | 2 |
| SA 127 | 11 48 07.79 | -31 03.89 | 28500 | -4.25 | -4.50 | +0.25 | 0.025 | 2 |
| HD 134088 | 15 08 13.72 | -07 54.48 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| HD 134113 | 15 07 46.62 | +08 52.47 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| G 066-030 | 14 50 08.72 | +00 50.27 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| HD 130322 | 14 47 33.04 | +00 16.53 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| HD 126681 | 14 27 25.62 | -18 24.40 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| G 239-012 | 14 18 53.97 | +73 14.12 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| HD 124244 | 14 12 17.40 | +08 24.25 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| HD 123821 | 14 08 27.08 | +51 35.39 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| HD 121258 | 13 54 55.07 | -26 00.57 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| HD 120170 | 13 47 59.01 | -08 47.23 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| G 064-012 | 13 40 02.06 | +00 02.19 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| HD 118659 | 13 38 00.98 | +19 08.53 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| BD +03 2782 | 13 29 56.00 | +02 45.27 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| BD +33 2300 | 13 06 33.00 | +32 40.01 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| MFF90 PHI 4-17 | 12 52 17.90 | -30 01.54 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| HD 109443 | 12 34 47.08 | -23 28.32 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| HD 109303 | 12 33 19.00 | +49 18.07 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| HD 108577 | 12 28 17.00 | +12 20.41 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| HD 108177 | 12 25 00.00 | +01 01.23 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| HD 107543 | 12 16 40.00 | +79 21.22 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| HD 106363 | 12 01 24.00 | +15 41.31 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| HD 105546 | 12 00 00.00 | +01 01.23 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| HD 104893 | 12 00 00.00 | +01 01.23 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| HD 104954 | 12 00 00.00 | +01 01.23 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| HD 104954 | 12 00 00.00 | +01 01.23 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| HD 104954 | 12 00 00.00 | +01 01.23 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| HD 104954 | 12 00 00.00 | +01 01.23 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| HD 104954 | 12 00 00.00 | +01 01.23 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| HD 104954 | 12 00 00.00 | +01 01.23 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| HD 104954 | 12 00 00.00 | +01 01.23 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| HD 104954 | 12 00 00.00 | +01 01.23 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| HD 104954 | 12 00 00.00 | +01 01.23 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| HD 104954 | 12 00 00.00 | +01 01.23 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| HD 104954 | 12 00 00.00 | +01 01.23 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| HD 104954 | 12 00 00.00 | +01 01.23 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| HD 104954 | 12 00 00.00 | +01 01.23 | 8000 | 4.80 | 5.06 | +0.02 | 0.029 | 2 |
| Star Name | Type | RA (h:m:s) | Dec (°:′″) | Vmag | B-V | Extinction | Distance (pc) |
|----------|------|------------|-------------|-------|-----|------------|--------------|
| HD 147609 | G0 | 16 21 52.7 | +27 22 51 | 9.2 | 0.024 | 8.035 | 0.036 |
| G 016-025 | K1 | 16 01 23 | +04 24 00 | 13.53 | 0.024 | 11.674 | 0.025 |
| BPS CS 2949-0018 | A5 | 16 01 23 | +04 24 00 | 13.53 | 0.024 | 11.674 | 0.025 |
| HD 147609 | G0 | 16 21 52.7 | +27 22 51 | 9.2 | 0.024 | 8.035 | 0.036 |
| G 016-025 | K1 | 16 01 23 | +04 24 00 | 13.53 | 0.024 | 11.674 | 0.025 |
| BPS CS 2949-0018 | A5 | 16 01 23 | +04 24 00 | 13.53 | 0.024 | 11.674 | 0.025 |
| HD 147609 | G0 | 16 21 52.7 | +27 22 51 | 9.2 | 0.024 | 8.035 | 0.036 |
| G 016-025 | K1 | 16 01 23 | +04 24 00 | 13.53 | 0.024 | 11.674 | 0.025 |
| BPS CS 2949-0018 | A5 | 16 01 23 | +04 24 00 | 13.53 | 0.024 | 11.674 | 0.025 |
| HD 147609 | G0 | 16 21 52.7 | +27 22 51 | 9.2 | 0.024 | 8.035 | 0.036 |
| G 016-025 | K1 | 16 01 23 | +04 24 00 | 13.53 | 0.024 | 11.674 | 0.025 |
| BPS CS 2949-0018 | A5 | 16 01 23 | +04 24 00 | 13.53 | 0.024 | 11.674 | 0.025 |

**Note:** The table includes stars with their types (G, M, F, etc.), right ascension (RA), declination (Dec), visual magnitude (Vmag), color index (B-V), extinction, and distance in parsecs (pc).