Separation of dwarf and giant stars with ROTSE–IIId

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Abstract. 136 stars which were known to be the members of open cluster NGC 752 were observed at $R$ band with ROTSE–IIId telescope located at the Turkish National Observatory (TUG) site. The data had been evaluated together with BV and 2MASS photometric data. A new practical method for separating dwarf and giant was described and applied. Evaluating the colour magnitude–diagrams with Padova isochrones revealed metallicity similar to the Sun and an age of 1.41 Gyr for the open cluster NGC 752.

Key words: Galaxy: open cluster and associations, stars: colour-magnitude diagrams, stars: giants

1. Introduction

One of the problems of the Galactic astronomy is the estimation of Galactic model parameters of giant stars in our Galaxy. In many studies, the Galactic model parameters are estimated without any discrimination between dwarfs and giants, whereas some researchers estimated model parameters only for certain star categories (e.g. Pritchet 1983, Bahcall & Soneira 1984, Buser & Kaeser 1985 and Mendez & Altena 1996). A very recent work is an example for this procedure stellar atmospheres to be sure for the identification. This paper is organized as follows. In Section 2 the BV, 2MASS and ROTSE data are presented. In Section 3 the method is applied to ROTSE and 2MASS data, and the separation of dwarf and giant stars is tested. In Section 4 colour-magnitude diagrams (CMDs) of NGC 752 is compared to the Padova isochrones. Finally, the conclusion is given in Section 5.

2. Observations

2.1. The BV and 2MASS Data

NGC 752=CO154+374 ($\alpha = 01^h57^m41^s, \delta = +37^\circ47'06"$; $l = 137\degr.13, b = -23\degr.25; J2000$) has been subject of many studies, because it is the nearest intermediate-age cluster, with 427 pc (Dzervitis & Paupers 1993) distance from the Sun. It is usually considered as metal-deficient with respect to the Sun, $[Fe/H] = -0.15 \pm 0.05$ dex, slightly reddened $E(B-V) = 0.035 \pm 0.005$, with distance module $(m-M) = 8.25 \pm 0.10$ (Daniel et al. 1994). Accurate proper motion and radial velocity measurements show that there are 136 probable member stars of the open cluster (Daniel et al. 1994). $V$ magnitudes and $(B-V)$ colour indices used in
 recently the 2MASS, including the Point-Source Catalogue and Atlas, has produced huge amounts of data to be explored in the coming years (Skrutskie et al. 1997). The photometric system comprises Johnson’s $\text{V}$ and 2MASS magnitudes given in Table 1. The $V \times (B - V)$ CMD in Fig. 1 shows that stars with $V < 10$ and $(B - V) > 0.80$ are giants.

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2MASS data of the 136 probable member stars in NGC 752 are obtained by Vizier\(^1\) in CDS and they are given in Table 1. We used the equations of Fiorucci & Munari (2003) for the determination of the total absorptions for the bands $V$, $J$, $H$ and $K_s$, i.e. $A(V) = 3.1E(B - V)$, $A(J) = 0.887E(B - V)$, $A(H) = 0.565E(B - V)$ and $A(K_s) = 0.382E(B - V)$. Thus the de-reddened magnitudes were obtained as follows: $V_0 = V - A(V)$, $J_0 = J - A(J)$, $H_0 = H - A(H)$ and $(K_s)_0 = K_s - A(K_s)$. The subscript “0” indicates de-reddened magnitude.

$J_0 \times V_0$, $H_0 \times V_0$ and $(K_s)_0 \times V_0$ diagrams for the cluster stars are given in Fig. 2. The solid lines represent the equations in Bilir et al. (2006), i.e.

\begin{align*}
J_0 &= 0.957V_0 - 1.079, \\
H_0 &= 0.931V_0 - 1.240, \\
(K_s)_0 &= 0.927V_0 - 1.292.
\end{align*}

14 stars below the lines are the giants in Fig. 1, whereas 122 stars above the lines are the dwarfs of the same cluster. The distribution of different star categories at different sides of the lines in three figures were presented here to confirm separation of dwarfs and giants.

2.2. ROTSE data

The Robotic Optical Transient Experiment (ROTSE-III) consists of four 0.45m worldwide robotic, automated telescopes situated at different locations on Earth. They are designed for fast (~6 sec) responses to Gamma-Ray Burst (GRB) triggers from satellites such as Swift. Each ROTSE telescope has a $1.85 \times 1.85$ deg$^2$ field of view, and uses a Marconi 2048 × 2048 back illuminated thinned CCD. These telescopes operate without filters, and have wide passband which peaks around 550 nm (Akerlof et al. 2003). In this work, we present optical observations of NGC 752 performed by ROTSE-IIIId, telescope located at Turkish National Observatory (TUG) site, Bakırtepe, Turkey. The observations took place between MJD 53637 (September 2005) and MJD 53649 (October 2005). A total of about 217 CCD frames were analyzed. After determining the instrumental magnitudes (Bertin & Arnouts, 1996), they were reduced to ROTSE magnitudes via comparing all the field stars with the USNO A2.0 $R$-band catalog. All the processes were done in an automated mode.

$R$-band magnitudes of the 136 stars are given in Table 1. ROTSE magnitudes are also de-reddened in order to homogenize the data. The total absorption for the $R$ band could be determined by the equation of Fiorucci & Munari (2003), i.e. $A(R) = 2.613E(B - V)$. Thus the de-reddened magnitude in $R$ becomes $R_0 = R - A(R)$.

\begin{figure}[h]
  \centering
  \includegraphics[width=\textwidth]{Fig1.png}
  \caption{V × (B − V) CMD of 136 probable member stars in NGC 752.}
\end{figure}

\begin{figure}[h]
  \centering
  \includegraphics[width=\textwidth]{Fig2.png}
  \caption{V and 2MASS magnitudes of 136 stars in NGC 752. (a) $J_0 \times V_0$, (b) $H_0 \times V_0$, and (c) $(K_s)_0 \times V_0$. The solid lines in diagrams were drawn according to eqs. (1), (2), and (3).}
\end{figure}

\textsuperscript{1} http://vizier.u-strasbg.fr/viz-bin/Vizier?-source=2MASS
Fig. 4. $R_0$ and 2MASS magnitudes of 136 stars in NGC 752. (a) $J_0 \times R_0$, (b) $H_0 \times R_0$, and (c) $K_{s0} \times R_0$. The solid lines in diagrams were drawn according to eqs. (5), (6), and (7).

3. Application of the method to ROTSE-IIId data

We used the following relation between the $V_0$ magnitude and the ROTSE-IIId magnitude $R_0$ for 136 stars of the open cluster NGC 752 (Fig. 3) in order to apply the method to ROTSE-IIId data:

$$V_0 = (1.019 \pm 0.006)R_0 + 0.092 \pm 0.070 \ (\sigma = 0.10),$$

(4)

Thus, substituting the value of $V_0$ in (4) into (1), (2), and (3) we obtain the relations between 2MASS and ROTSE-IIId magnitudes, i.e.

$$J_0 = 0.975R_0 - 0.991,$$

(5)

$$H_0 = 0.949R_0 - 1.154,$$

(6)

$$(K_{s0}) = 0.945R_0 - 1.207.$$  

(7)

The diagrams $J_0 \times R_0$, $H_0 \times R_0$ and $(K_{s0}) \times R_0$ for the NGC 752 cluster stars and the line corresponding to the eqs. (5), (6), and (7) are given in Fig. 4. One can see that dwarfs and giants lie at opposite sides of the line in these figures, especially the relation between $(K_{s0}) \times R_0$ (Fig. 4c) is the most successful in separating of the two different star categories.

4. Age estimation for the open cluster NGC 752 via two photometries

We estimated the age of the open cluster NGC 752 by the means of BV and 2MASS data to show the advantage. The absolute magnitudes of the stars were determined by the corresponding apparent magnitudes and the distance module of the cluster. The Padova isochrones were taken from Girardi et al. (2002) and Bonatto, Bica & Girardi (2004) for BV\(^2\) and 2MASS\(^3\) photometry, respectively. The isochrone sets were computed with updated opacities, and equations of state, and a moderate amount of convective overshoot. The basic isochrone set presented in Girardi et al. (2002) covers a very wide range of initial masses (from 0.15 to $\sim 100M_\odot$), metallicities, and photometric systems, being well suited for studies of clusters of all ages.

The isochrones mentioned above were fitted to the CMDs in Figs. 5-7 for two sets of chemical compositions, i.e. $Z=0.019$, $Y=0.273$ (panel a) and $Z=0.008$, $Y=0.250$ (panel b). The isochrones in Fig. 5a fits to the main-sequence and turn-off segments of the $M_V \times (B-V)_0$ diagram and reveal an age of $t = 1.26$ Gyr, whereas in Fig. 5b, the isochrones could be fitted only to the giant branch of the same CMD, resulting a larger age, i.e. $t = 1.78$ Gyr. The isochrones could not be fitted to all segments of the $M_J \times (J-H)_0$ diagram in Fig. 6 either. In Fig. 6a the fit is better to the main-sequence and turn-off segments, however it is only to the giant branch in Fig. 6b. The best fit is accomplished with the isochrone of age $t = 1.41$ Gyr to the $M_J \times (J-K_s)_0$ in Fig. 7a. In fact, the isochrone fits to all segments, main-sequence, turn-off and giant branch, for a metallicity close to the solar one which is expected (Daniel et al. 1994). Thus, the comparison of the six diagrams in Figs. 5-7 reveals that the CMD $M_J \times (J-K_s)_0$ is the best one which fits for the age estimation.

\(^2\) http://pleiadi.pd.astro.it/isoc\_photsys.02/isoc\_photsys.02.html

\(^3\) http://pleiadi.pd.astro.it/isoc\_photsys.01/isoc\_2mass/index.html
5. Conclusion

In this study, we have reduced the relations between the 2MASS and \( V \) magnitudes by which field dwarfs and giants can be separated, to the USNO A2.0 \( R \)-band magnitudes. The \( R_0 \) magnitudes of 136 stars in open cluster NGC 752 were transferred to the \( V_0 \) magnitudes, and the relations between \( J_0 \), \( H_0 \), \( (K_s)_0 \) and \( R_0 \) were derived by means of the relations between \( J_0 \), \( H_0 \), \( (K_s)_0 \) and \( V_0 \) given by Bilir et al. (2006). Dwarf and giant stars identified by the CMD of open cluster NGC 752 lie at different sides of the line representing the relation between the 2MASS and \( R_0 \) magnitudes, in the \( J_j \times R_0 \), \( H_0 \times R_0 \) and \( (K_s)_0 \times R_0 \) diagrams. The best one is the last diagram, i.e. \( (K_s)_0 \times R_0 \). Thus, dwarf-giant separation could be carried out also in the ROTSE-IIId data. Proven to be successful, this practical method can provide good contributions to the studies of Galactic model parameters in which separation of dwarfs and giants were needed.

A set of Padova isochrones were fitted to the CMDs of the open cluster NGC 752 using BV and 2MASS photometric data. It turned out that the isochrone with chemical composition \( Z=0.019 \) and \( Y=0.273 \) which reveals an age of 1.41 Gyr for the open cluster NGC 752 could be fitted to all segments, i.e. main-sequence, turn-off and giant branch, of the \( M_J \times (J-K_s)_0 \) two-colour diagram. This result is very close to the age 1.24±0.20 Gyr which Salaris, Weiss & Percival (2004) calculated from the morphology of 71 open clusters in our Galaxy. The metal-abundance of the cluster given by Daniel et al. (1994), i.e. \([Fe/H] = -0.15 \pm 0.05 \) dex, is a strong confirmation for our result.

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Table 1. BV, ROTSE and 2MASS magnitudes and its errors of 136 probable member stars of open cluster NGC 752. ID name is the same as Daniel et al. (1994), and the coordinates are for the epoch 2000.

| ID  | α               | δ               | V   | B-V | R   | J   | H   | K_s |
|-----|-----------------|-----------------|-----|-----|-----|-----|-----|-----|
| 043 | 05 31.04         | +37 29.36       | 11.4 | 0.470 | 10.970 | 0.010 | 10.343 | 0.019 | 10.184 | 0.024 | 10.151 | 0.020 |
| 044 | 05 31.70         | +37 28.59       | 13.7 | 0.004 | 9.144 | 0.012 | 8.615 | 0.017 | 8.378 | 0.019 |
| 045 | 05 32.36         | +37 29.98       | 11.6 | 0.009 | 9.489 | 0.007 | 9.135 | 0.001 | 8.778 | 0.018 |
| 051 | 05 33.91         | +37 52.83       | 8.922 | 0.002 | 7.165 | 0.006 | 6.869 | 0.001 | 6.521 | 0.016 |
| 057 | 05 34.79         | +37 34.93       | 13.9 | 0.007 | 12.402 | 0.019 | 11.936 | 0.024 | 11.108 | 0.019 | 10.942 | 0.020 |
| 059 | 05 33.67         | +37 50.14       | 9.496 | 0.013 | 8.993 | 0.006 | 8.640 | 0.016 | 8.377 | 0.018 |
| 059 | 05 35.19         | +37 50.31       | 9.569 | 0.005 | 9.090 | 0.017 | 8.795 | 0.023 | 8.371 | 0.016 |
| 060 | 05 36.28         | +38 08.20       | 13.6 | 0.000 | 12.700 | 0.019 | 12.182 | 0.018 | 11.798 | 0.021 | 11.743 | 0.021 |
| 061 | 05 37.68         | +37 34.04       | 10.152 | 0.003 | 9.442 | 0.011 | 9.293 | 0.018 | 9.103 | 0.015 | 9.062 | 0.016 |
| 062 | 05 37.67         | +37 59.52       | 9.285 | 0.011 | 8.966 | 0.009 | 8.902 | 0.020 | 8.718 | 0.021 | 8.709 | 0.020 |
| 063 | 05 39.21         | +37 52.53       | 8.972 | 0.012 | 8.775 | 0.008 | 8.648 | 0.012 | 8.550 | 0.017 | 8.504 | 0.017 |
| 065 | 05 39.77         | +37 34.24       | 13.9 | 0.009 | 13.027 | 0.015 | 12.407 | 0.021 | 11.850 | 0.024 | 11.888 | 0.024 |
| 066 | 05 40.93         | +38 08.21       | 13.5 | 0.007 | 12.640 | 0.013 | 12.063 | 0.018 | 11.590 | 0.023 | 11.598 | 0.023 |
| 072 | 05 41.40         | +37 42.66       | 13.9 | 0.005 | 13.060 | 0.018 | 12.485 | 0.022 | 11.935 | 0.024 | 12.073 | 0.024 |
| 073 | 05 41.56         | +37 49.26       | 8.855 | 0.001 | 8.609 | 0.001 | 8.330 | 0.007 | 8.081 | 0.011 | 8.047 | 0.011 |
| 075 | 05 41.53         | +37 32.32       | 13.8 | 0.003 | 13.027 | 0.017 | 12.407 | 0.020 | 11.850 | 0.024 | 11.888 | 0.024 |
| 076 | 05 41.50         | +37 50.27       | 8.945 | 0.017 | 8.785 | 0.012 | 8.640 | 0.013 | 8.550 | 0.017 | 8.504 | 0.017 |
| 081 | 05 43.51         | +38 07.25       | 13.6 | 0.008 | 13.027 | 0.020 | 12.407 | 0.022 | 11.850 | 0.024 | 11.888 | 0.024 |
| 084 | 05 44.79         | +37 34.55       | 13.9 | 0.006 | 13.027 | 0.018 | 12.407 | 0.022 | 11.850 | 0.024 | 11.888 | 0.024 |
| 086 | 05 45.51         | +37 48.57       | 13.5 | 0.006 | 13.027 | 0.018 | 12.407 | 0.022 | 11.850 | 0.024 | 11.888 | 0.024 |
| 088 | 05 45.77         | +37 52.56       | 9.285 | 0.011 | 8.966 | 0.009 | 8.902 | 0.020 | 8.718 | 0.021 | 8.709 | 0.020 |
| 089 | 05 45.77         | +37 52.56       | 9.285 | 0.011 | 8.966 | 0.009 | 8.902 | 0.020 | 8.718 | 0.021 | 8.709 | 0.020 |
| 091 | 05 45.77         | +37 52.56       | 9.285 | 0.011 | 8.966 | 0.009 | 8.902 | 0.020 | 8.718 | 0.021 | 8.709 | 0.020 |
| 091 | 05 45.77         | +37 52.56       | 9.285 | 0.011 | 8.966 | 0.009 | 8.902 | 0.020 | 8.718 | 0.021 | 8.709 | 0.020 |
| 091 | 05 45.77         | +37 52.56       | 9.285 | 0.011 | 8.966 | 0.009 | 8.902 | 0.020 | 8.718 | 0.021 | 8.709 | 0.020 |
| 091 | 05 45.77         | +37 52.56       | 9.285 | 0.011 | 8.966 | 0.009 | 8.902 | 0.020 | 8.718 | 0.021 | 8.709 | 0.020 |
| 091 | 05 45.77         | +37 52.56       | 9.285 | 0.011 | 8.966 | 0.009 | 8.902 | 0.020 | 8.718 | 0.021 | 8.709 | 0.020 |
| 091 | 05 45.77         | +37 52.56       | 9.285 | 0.011 | 8.966 | 0.009 | 8.902 | 0.020 | 8.718 | 0.021 | 8.709 | 0.020 |
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