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Near-infrared study of open clusters Teutsch 10 and Teutsch 25

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Abstract

The astrophysical parameters have been estimated for two unstudied open star clusters Teutsch 10 and Teutsch 25 using the Two Micron All Sky Survey (*2MASS*) database. Radius is estimated as 4.5 arcmin for both clusters using radial density profiles. We have estimated proper motion values in both RA and DEC directions as 2.28 ± 0.3 and -0.38 ± 0.11 mas yr^{-1} for Teutsch 10 and 0.48 ± 0.3 and 3.35 ± 0.16 mas yr^{-1} for Teutsch 25 using *PPMXL*[1] catalog. By estimating the stellar membership probabilities, we have identified 30 and 28 most likely members for Teutsch 10 and Teutsch 25 respectively. We have estimated the reddening as $E(B-V) = 0.96 \pm 0.3$ mag for Teutsch 10 and 0.58 ± 0.2 mag for Teutsch 25, while the corresponding distances are 2.4 ± 0.2 and 1.9 ± 0.1 kpc. Ages of 70 ± 10 Myr for Teutsch 10 and 900 ± 100 Myr for Teutsch 25 are estimated using the theoretical isochrones of metallicity $Z = 0.019$. The mass function slopes are derived as 1.23 ± 0.30 and 1.09 ± 0.35 for Teutsch 10 and Teutsch 25 respectively. Estimated mass function slope for both the clusters are close to the Salpeter value ($x = 1.35$) within the errors. Estimated values of dynamical relaxation time are found to be less than cluster's age for these objects. This concludes that both objects are dynamically relaxed. The possible reason for relaxation may be due to dynamical evolution or imprint of star formation or both.

Keywords: Galaxy; Open cluster and associations; Individual; Teutsch 10 and Teutsch 25; Proper-motion; Luminosity and mass function

1. Introduction

Open clusters (OCs) are important objects to understand star formation process in the Galaxy and in star clusters (Lada and Lada, 2003). Piskunov et al. (2006) estimated that the total number of open clusters in the Galactic disk to be the order of 10^5 at present. Gaburov and Gieles (2008) have compiled statistically significant samples of clusters of known distance, age and metallicity. By using the colour-magnitude and colour-colour diagrams of star clusters, it is possible to estimate the fundamental parameters (age, distance and reddening). These fundamental parameters play most important role to understand about the theories of star formation and stellar evolution process.

The *2MASS* data has been proved very powerful tool in the investigation of the structure and stellar content of open star clusters (Bonatto and Bica, 2003; Soares and Bica, 2002; Bica et al., 2003; Selim et al., 2014). In the recent years, more than thousands open clusters were discovered by analysing *2MASS* data (Kronberger et al., 2006; Froebrich et al., 2007; Koposov et al., 2008; Glushkova et al., 2010). The reality of these recently discovered open clusters was confirmed by means of their $J, (J-H)$ and $K_s, (J-K_s)$ colour magnitude diagram analysis and their fundamental parameters were estimated. Most of the open clusters are embedded in the Galactic disk and also affected by field star contamination, it is

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[1] http://vizer.cfa.harvard.edu/vizbin/VizieR?-source=I/317.

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necessary to discriminate between members and non members of the clusters. Recent all-sky proper motion catalogs (e.g. Roeser et al., 2010; Zacharias et al., 2013) provide clues to estimate cluster membership. The rate of clusters discovery has significantly increased over the last decades, which mainly includes GLIMPSE (Benjamin et al., 2013), UKIDSS-GPS (Lucas et al., 2008), VISTA-VVV (Minniti et al., 2010) and WISE (Wright et al., 2010) surveys.

Open clusters are the ideal objects for the estimation of initial mass function (IMF), since all the relevant parameters (age, distance, reddening, metallicity, etc.) can be estimated more accurately. Determination of IMF in intermediate age open star clusters is very difficult and we can estimate only present day mass function because MF changes due to dynamical effects. Field region stars are very complex for mass function analysis since they are the collection of different origins, birth circumstances and different initial mass stars.

In the present study, our aim is to estimate the fundamental parameters of two open clusters Teutsch 10 and Teutsch 25 using 2*MASS* near-infrared data. Our candidates Teutsch 10 and Teutsch 25 are lying in second and third galactic quadrants respectively and both are close to the Galactic plane. The only available information about these objects are the coordinates and the apparent diameters, which were obtained from WEBDA[2] site. We have determined the mean proper motion of these clusters in both directions (Right ascension and declination) using Position and Proper Motion Extended-L (*PPMXL*) database.

This paper is organized as follows. Section 2 presents the description of used data. Cluster structure is described in Section 3. Proper motion study is discussed in Section 4. Fundamental parameters are estimated in Sections 5 and 6 respectively. Luminosity and mass function are presented in Section 7. Dynamical state of the target objects are described in Section 8. Finally, the conclusions are devoted in Section 9.

2. Data used

The purpose of the present study is to derive the astrophysical parameters of clusters Teutsch 10 and Teutsch 25 by using 2*MASS* Point Source catalog (Cutri et al., 2003). In both clusters we extracted the 2*MASS* photometry from VizieR,[3] in a radius $R_{ext} = 20$ arcmin. The 2*MASS* (Skrutskie et al., 2006) uses two highly automated 1.3 m telescope (one at Mt. Hopkins, Arizona (AZ), USA and other at CTIO, Chile) with a 3-channel camera ((256×256) array of HgCdTe detectors in each channel). This 2*MASS* photometric catalog provides $J(1.25\ \mu m)$, $H(1.65\ \mu m)$ and $Ks(2.17\ \mu m)$ band photometry for millions of galaxies and nearly a half-billion stars (Carpenter, 2001). Identification maps for the clusters are taken from Leicester Database and Archive Service (LEDAS) as shown in Fig. 1.

The proper motion of the investigated cluster has been estimated using *PPMXL* catalog of Roeser et al. (2010). In this catalog, we can find the mean positions and proper motions for all objects of magnitudes down to $V \sim 20$ mag. Mean errors of the proper motions vary from $\sim$4 mas yr^{-1} for $J \leqslant 10$ mag to more than $\sim$10 mas yr^{-1} at $J \geqslant 16$ mag (Khalaj and Baumgardt, 2013). Photometric errors, given in 2*MASS* catalog for J, H and K_s bands are plotted against J magnitudes in Fig. 2. This figure shows that the mean error in J, H and K_s band is $\leqslant$0.05 at $J \sim 14.0$ mag. The error becomes $\sim$0.09 at $J \sim 15$ mag.

3. Radial density profile

To calculate the cluster extent, we have established the radial density profiles (RDPs) for the clusters Teutsch 10 and Teutsch 25. We have divided the observed area of these clusters into many concentric rings. The number density, ρ_i, in the ith zone is estimated by using the formula, $\rho_i = \frac{N_i}{A_i}$. Where N_i is the number of cluster stars and A_i is the area of the ith zone. Fig. 3 shows RDPs for Teutsch 10 and Teutsch 25. The background density level with errors is also shown with dotted lines. Background density is determined by using the region from 10 to 20 arcmin out side the cluster radius. Errors in background density are determined from sampling statistics $(1/\sqrt{(N)}$. Cluster's RDP flattens at $r \sim 4.5$ arcmin for both the clusters and begin to merge with the background stellar density as shown in Fig. 3. Therefore, we have taken 4.5 arcmin as cluster radii for both the clusters. A solid continuous line in the RDPs represents the King (1962) profile:

$$f(r) = f_b + \frac{f_0}{1 + (r/r_c)^2}$$

where f_0 is the central density, r_c is core radius and f_b is the background density. By fitting the King model to the RDPs, we have estimated the structural parameters of clusters Teutsch 10 and Teutsch 25, which are listed in Table 1.

The density contrast parameter $\delta_c = 1 + \frac{f_0}{f_b}$ is determined for the clusters under study. The estimated values of δ_c are found to be 2.8 and 2.6 for the clusters Teutsch 10 and Teutsch 25 respectively which are listed in Table 1. Present estimation of δ_c is lower than the values ($7 \leqslant \delta_c \leqslant 23$) given for compact star clusters by Bonatto and Bica (2009). This indicates Teutsch 10 and Teutsch 25 are the sparse clusters.

The tidal radii of open clusters depend on both combined effects of Galactic tidal fields and subsequent internal relaxation dynamical evolution of clusters (Allen and Martos, 1988). To estimate the tidal radius, we have used the following relation as given by Jeffries et al. (2001).

$$R_t = 1.46 \times (M_c)^{1/3}$$

[2] http://obswww.unige.ch/webda.
[3] vizer.u-strasbg.fr/vizbin/VizieR?-source=II/246.