Mem. S.A.It. Vol. 87, 699

Memorie della

The Galactic star cluster NGC 4337: estimates of its photometric and dynamical mass

A. F. Seleznev[1], R. Capuzzo Dolcetta[2], and G.Carraro[3,4]

[1] Astronomical Observatory, Ural Federal University, Mira str. 19, Ekaterinburg, 620002, Russia, e-mail: anton.seleznev@urfu.ru
[2] Dipartimento di Fisica, Sapienza, Università di Roma, P.le A. Moro 5, I-00165 Roma, Italy
[3] ESO, Alonso de Cordova 3107, 19001, Santiago de Chile, Chile
[4] Dipartimento di Fisica e Astronomia, Università di Padova, Vicolo Osservatorio 3, I-35122 Padova, Italy

Abstract. In this contribution we discuss various estimates of the mass of NGC 4337, an old open cluster located in the inner Galactic disk. We derive its mass in different ways. First, we obtain a lower estimate of the cluster mass using the surface density profile of the cluster and its luminosity and mass function by means of star counts out of a photometric data set in the UBVI passbands. This data set is also used to derive fundamental cluster parameters. Second, we obtain dynamical estimates of the cluster mass as based on a large survey of cluster star radial velocities. The dynamical estimates correspond to significantly larger values than those from star count estimates. We can roughly match these two estimate sets taking into account the contribution of invisible mass in the form of both low mass stars and remnants of high mass stars in the cluster.

Key words. (Galaxy): open clusters and associations: general – (Galaxy): open clusters and associations: individual: NGC 4337

1. Introduction

In this study we make use of a photometric and spectroscopic data-set to derive the present-day mass of the Galactic star cluster NGC 4337. The details of the observations are reported in Seleznev et al. (2016).

We obtain a mean cluster radial velocity and velocity dispersion (with the assumption of spherical symmetry in the velocity distribution) of $\langle v_r \rangle$=-17.85±0.28 km s^{-1} and $\langle \sigma \rangle$=1.48±0.13 km s^{-1}. We refine here the cluster distance and reddening of the cluster by fitting the CMD of NGC 4337 using the radial velocity members only. We find that an isochrone of 1.5 Gyr better reproduces the shape of the TO and the magnitude of the clump. This convincing fit yields a reddening E(V-I) = 0.385±0.005, and an apparent visual distance modulus $(m\text{-}M)_V$ = 12.72±0.02. This implies that the cluster distance is 2.2±0.1 kpc from the Sun, slightly lower than Carraro et al. (2014) estimate.

2. Cluster mass estimates

Surface density profiles $F(r)$ were derived by kernel estimator (Seleznev 2016) for different limiting magnitudes V. The integration of surface density profiles (Seleznev 2016) gave the estimate of the cluster mass of $\mathfrak{M} = 730 \pm 110\ M_\odot$ for stars brighter than $V = 20$ mag.

The luminosity function of NGC 4337 was obtained by kernel estimator (Prisinzano et al. 2001) and then the mass function (MF) of the cluster was derived in the magnitude range $V \in [14.5; 20]$. A least squares regression over the logarithmic MF yields a MF slope of -2.57 ± 0.10 (in this scale the standard Salpeter slope is -2.35). The mass-luminosity relation $m = m(V)$ was taken from Padova suite of models (Bressan et al. 2012). The mass function yields the cluster mass estimate of $1040 \pm 180\ M_\odot$ in the same magnitude interval $V < 20$ mag.

The difference in these two estimates are explained by the different mean values of the stellar background density used in the two methods. Taking into account the indications on a larger cluster size, the larger mass estimate seems to be more reliable.

The dynamical cluster mass estimates were derived in three ways.

The first one is based on the virial ratio Q_3 for cluster member stars and yields the estimate of $M_3 = 9607 \pm 147$ $\mathrm{M}_\odot$. This estimate implies that the cluster is in the virial equilibrium, and the virial ratio of the whole cluster is equal to unity. In this case the mass estimate becomes $M_3 = Q_3 M_*$, where M_* is the mass of cluster member stars. The error here does not include the error propagation due to uncertainty in the star radial velocities, distances and angular coordinates.

The second one is the traditional virial estimate of $M_{vir} = 8400 \pm 1800\ M_\odot$ and uses the velocity dispersion value from Section 1.

The third one takes into account the Galactic gravitational field and non-stationarity of the cluster and is based on the formula proposed by Danilov & Loktin (2015). It yields the value of $M_d = 6800 \pm 2100\ M_\odot$. In order to obtain two latter estimates the values of R_u, $\overline{R}$ and $\overline{r^2}$ were derived through the Monte Carlo modeling of the spatial distribution of stars around the cluster center $f(r)$, which in turn was derived by de-projecting the observed surface density profile $F(r)$ of the cluster. ($R_u = \overline{1/r_i}^{-1}$ is the mean inverse star distance to the cluster centre, $\overline{R} = \overline{1/r_{ij}}^{-1}$ is the mean inverse star-to-star distance, $\overline{r^2}$ is the mean square of the star distance to the cluster centre). Parameters of the Galactic potential were taken in accordance with the Galactic potential model of Kutuzov & Osipkov (1980). Arguments in favour of this model are listed in Seleznev (2016).

How we can explain the difference between star count estimates and dynamical ones?

The contribution of invisible stars (low mass, faint, stars of the cluster and high mass remnants), can partly explain this difference. On another side, it is possible that star counts could not reveal the vast cluster corona, so the mass estimates obtained by star counts and by the mass function are underrated. Another possibility is that the velocity dispersion is overestimated and results in larger dynamical estimates. The reason for that can be binarity of sample stars or inclusion of non-member stars into the sample.

Acknowledgements. The work of A.F.Seleznev was supported by the Ministry of Education and Science of the Russian Federation (state contract No. 3.1781.2014.K, registration number 01201465056). The travel of A.F.Seleznev to Cosmic-Lab conference was supported by Act 211 Government of the Russian Federation, contract No. 02.A03.21.0006.

References

Bressan, A., et al. 2012, MNRAS, 427, 127
Carraro, G., Monaco, L., & Villanova, S. 2014, A&A, 568, A86
Danilov, V.M., Loktin, A.V. 2015, Astrophys. Bull., 70, 414
Kutuzov, S.A., Osipkov, L.P. 1980, Soviet Ast., 24, 17
Prisinzano, L., et al. 2001, A&A, 369, 851
Seleznev, Anton F. 2016, MNRAS, 456, 3757
Seleznev, Anton F., et al. 2016, MNRAS, submitted