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Determination of the mass of open clusters using data from the eDR3 catalogue

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Abstract. With the availability of Gaia data catalogs and the existence of automated isochrone fitting methods, the study of open clusters has undergone great advances in recent years. Its fundamental parameters have been, consequently, estimated on a larger scale and with better precision. However, important parameters such as the total masses of these objects, the details of individual and binary star populations, and the existence of mass segregation have not been adequately studied. In this context, this work presents a new method for determining individual masses, including binary stars. This method allows the study of the total mass of open clusters, as well as details of the population of binaries through their mass functions. To validate the method and its efficiency, we used synthetic agglomerates with previously determined parameters. With the method validated, we apply the procedure for clusters of a recent catalog of fundamental parameters of our group, obtained from GAIA (eDR3). Key results acquired include obtaining the detailed mass function for individual, primary and secondary star populations, as well as the total masses for 900 clusters.

Resumo. Com a disponibilização dos catálogos de dados Gaia e a existência de métodos de ajuste de isócronas automatizados, o estudo de aglomerados abertos vem passando por grandes avanços nos últimos anos. Seus parâmetros fundamentais vêm, consequentemente, sendo estimados em maior escala e com melhor precisão. Entretanto, parâmetros importantes como as massas totais desses objetos, os detalhes das populações de estrelas individuais e binárias e a existência de segregação de massa não foram estudados de maneira adequada. Nesse contexto, neste trabalho apresentamos um novo método de determinação de massas individuais, inclusive de estrelas binárias. Esse método permite estudar a massa total dos aglomerados abertos, assim como detalhes da população de binárias através de suas funções de massa. Para validar o método e sua eficiência, utilizamos aglomerados sintéticos com parâmetros previamente determinados. Com o método validado, aplicamos o procedimento para aglomerados de um recente catálogo de parâmetros fundamentais de nosso grupo, obtido do GAIA (eDR3). Os principais resultados adquiridos incluem a obtenção da função de massa detalhada para as populações de estrelas individuais, primárias e secundárias, bem como as massas totais para 900 aglomerados.

Keywords. Galaxy: open clusters and associations: general

1. Introduction

Mass is one of the fundamental parameters of star clusters. The relationship of mass with other parameters for these objects allows us to obtain important information for the understanding of our Galaxy and stellar evolution. For example, the mass-radius relationship is important to understand the dynamic evolution of these objects, since during their evolution they undergo numerous encounters with molecular clouds where they form and, in the process, can lose mass and reduce their size (Joshi et al., 2016; Spitzer 1958). Clusters are also affected by external forces interacting with the Galactic potential. Cluster dissolution times depend on several factors such as initial cluster mass, orbital location, and internal structure. More massive clusters are believed to survive longer than low-mass ones. Despite its importance, the study of mass has been limited in the literature due to its difficulty.

A big leap in terms of cluster sample size was given by Piskunov et al. (2008), who analyzed a sample of hundreds of open clusters close to the Sun, selected from the ASCC-2.5 (photometric and astrometric) catalogue. Kharchenko et al. (2007). The main objective was to derive the tidal radii and masses of each cluster by fitting King profiles King (1962).

Our work, therefore, comes with a proposal for a new method to determine the masses of open clusters using data from GAIA eDR3 Gaia Collaboration et al., (2021).

2. Methods

One of the fundamental parts of this work is the generation of synthetic clusters. These are created by a python script, in which we have the autonomy to define several parameters such as age, distance, metallicity, redness, fraction of binaries, and cluster membership. In addition, our synthetic clusters have information about the mass of each member star and their magnitudes, coming from an isochrone *grid* that make use of Gaia filters (G, G_{BP}, G_{RP}).

Supported by synthetic clusters, we propose a new method for determining the mass of stars that are members of open clusters. We refer to this method as Individual Mass Determination (hereinafter DMI).

Essentially, we superimpose the CMD of a synthetic cluster on the CMD of the observed cluster. The synthetic star that is closest in magnitude to the observed star will have its mass assigned to the observed star. The distinction between individual and binary stars also occurs in this step.

With the masses of individual stars determined, we calculated the total masses of open clusters by performing mass function integration and extrapolating for low-mass stars that were unobserved or excluded due to high photometric errors.

We used two integration methods to determine the total masses:

– Integrated FM is the determination of the total mass by integrating the mass function with all observed stars added to the extrapolated mass value, referring to the unobserved stars.

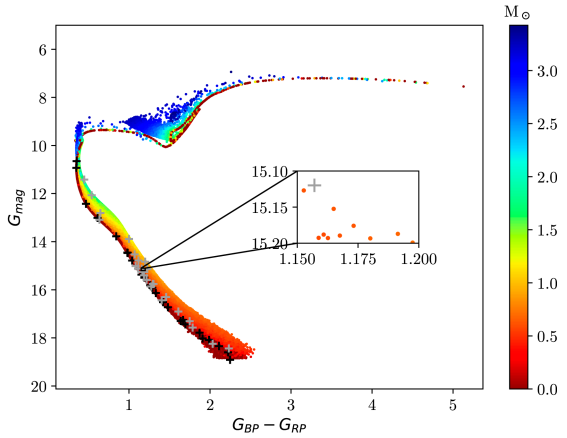

Figure 1. Shortest distance between the observed star (gray) and the synthetic star (orange). Synthetic stars dispersed in a color spectrum and observed stars cross in grey.

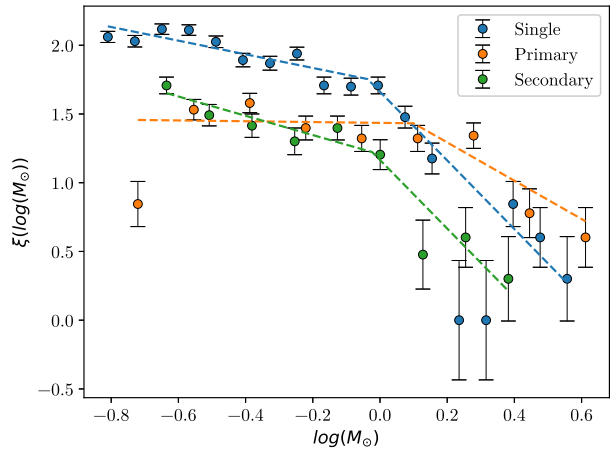

Figure 2. Pleiades present day mass functions for single, primary and secondary stars. The slopes and turning points for the single star population are $\alpha_A = -2.43 \pm 0.45$, $\alpha_B = 0.05 \pm 0.10$ and $M_c = -0.04 \pm 0.05$, for primary stars $\alpha_A = -2.56 \pm 0.65$, $\alpha_B = -0.69 \pm 0.18$ and $M_c = -0.03 \pm 0.07$ and the secondary stars $\alpha_A = -1.34 \pm 0.93$, $\alpha_B = -0.04 \pm 0.48$ and $M_c = 0.1 \pm 0.24$.

– Detailed FM is the integration of each observed mass function of individual stars, primary and secondary. For these mass functions, we perform an extrapolation of the unobserved mass parcel and sum their integration values in order to obtain the final total mass.

3. Results

Knowing the total masses of the synthetic agglomerates, we verified that the traditional method (mass-luminosity ratio) has a relative error greater than 20% for most cases of intermediate age. Our method, under the same conditions, presented an error of 10%, in addition to determining the masses of binary stars with good precision.

Our results also indicated that the integrated MF is the most efficient method to recover the total masses of the clusters. Details of this MF can be seen in 2.

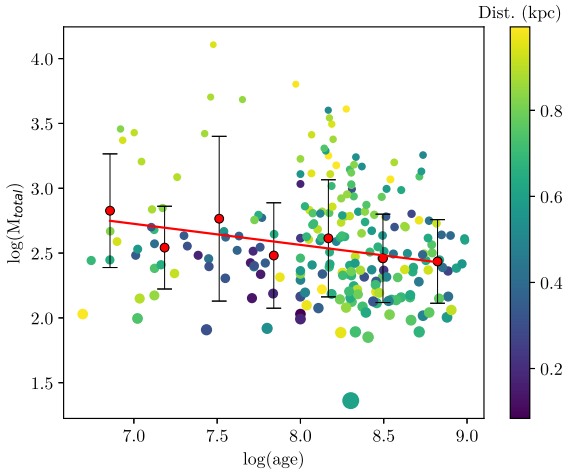

Figure 3. Top left: younger clusters tend to have higher total masses and, as they evolve, they lose mass at a rate of 48 $M_\odot$

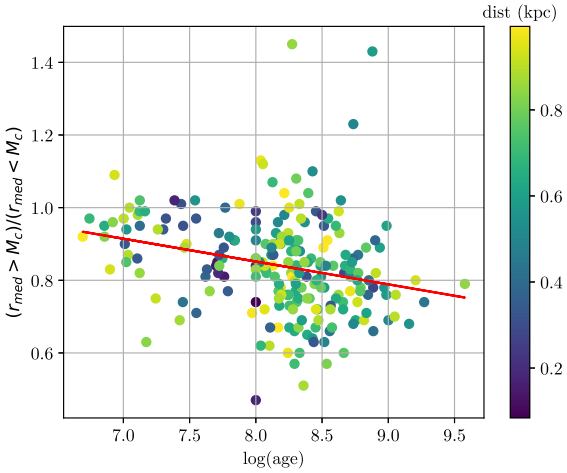

Figure 4. Mass segregation increases with age.

4. Conclusions

In this work, we calculated the total masses of 900 open clusters, by employing our method of determination of individual star masses. In our results, we noticed that populations of single, primary, and secondary stars have different slopes of mass functions. This data also allowed us to investigate relationships of fundamental parameters of the clusters, such as age, degree of mass segregation, and the overview of the total masses in our Galaxy.

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