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Investigating dynamical properties of evolved Galactic open clusters*

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ABSTRACT

Context. The stellar content of Galactic open clusters is gradually depleted during their evolution as a result of internal relaxation and external interactions. The final residues of the long-term evolution of open clusters are called open cluster remnants. These are sparsely populated structures that can barely be distinguished from the field.

Aims. We aimed to characterise and compare the dynamical states of a set of 16 objects catalogued as remnants or remnant candidates. We employed parameters that are intimately associated with the dynamical evolution: age, limiting radius, stellar mass, and velocity dispersion. The sample also includes 7 objects that are catalogued as dynamically evolved open clusters for comparison purposes.

Methods. We used photometric data from the 2MASS catalogue, proper motions and parallaxes from the *Gaia* DR2 catalogue, and a decontamination algorithm that was applied to the three-dimensional astrometric space of proper motions and parallaxes ($\mu_\alpha, \mu_\delta, \varpi$) for stars in the objects' areas. The luminosity and mass functions and total masses for most open cluster remnants are derived here for the first time. Our analysis used predictions of N-body simulations to estimate the initial number of stars of the remnants from their dissolution timescales.

Results. The investigated open cluster remnants present masses (M) and velocity dispersions (σ_v) within well-defined ranges: M between ~10−40 $M_\odot$ and σ_v between ~1−7 km s^{-1}. Some objects in the remnant sample have a limiting radius $R_\mathrm{lim} \lesssim 2$ pc, which means that they are more compact than the investigated open clusters; other remnants have R_lim between ~2−7 pc, which is comparable to the open clusters. We suggest that cluster NGC 2180 (previously classified as an open cluster) is entering a remnant evolutionary stage. In general, our clusters show signals of depletion of low-mass stars. This confirms their dynamically evolved states.

Conclusions. We conclude that the open cluster remnants we studied are in fact remnants of initially very populous open clusters ($N_0 \sim 10^3-10^4$ stars). The outcome of the long-term evolution is to bring the final residues of the open clusters to dynamical states that are similar to each other, thus masking out the memory of the initial formation conditions of star clusters.

Key words. open clusters and associations: general

1. Introduction

Galactic open clusters (OCs) gradually lose their stellar content and eventually dissolve. Their evolution can be split into three phases: (i) the first lasts for ~3 Myr, during which the cluster is embedded in its progenitor molecular cloud and stars are still forming; (ii) the clusters that survive the early gas-expulsion phase (e.g. supernova explosions and stellar winds) and are largely gas free and their overall dynamics is dominated by stellar mass loss (Portegies Zwart et al. 2007, 2010); and finally, (iii) the long-term evolutionary phase ($t \gtrsim 100$ Myr), when timescales for stellar mass loss through stellar evolution are considerably longer than dynamical timescales and purely dynamical processes dominate the evolution of the cluster. Internal and external forces (two-body or higher-order interactions, interactions with the Galactic tidal field, collisions with molecular clouds, and disc shocking) contribute to the decrease of total mass in the cluster (Pavani et al. 2011, 2001).

The final residue of an OC evolution is often called open cluster remnant (OCR). Bica et al. (2001) assumed that a cluster becomes significantly depopulated with a remnant appearence after losing two-thirds of its initial stellar content. They also suggested the acronym POCR (possible open cluster remnant) for remnant candidates, that is, objects presenting significant number density contrast with respect to the general Galactic field, but with dubious evolutionary sequences in colour-magnitude diagrams (CMDs) due to large contamination by field stars. As stated by Carraro et al. (2007), the application of the criterion established by Bica et al. (2001) is quite straightforward in the case of simulated clusters. On the other hand, this criterion is difficult to use with real clusters, since a reliable estimate of the initial number of stars is inaccessible from observations. In this context, how can we objectively distinguish OCRs from well-known OCs? The present work is a contribution in this sense. In addition to being heavily underpopulated in relation to the OCs, the studied OCRs present compatible masses between them, they

* Table A.1 is only available at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsarc.u-strasbg.fr/viz-bin/qcat?J/A+A/624/A8