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Dynamics of Multiple Stellar Populations in Globular Clusters

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Abstract. The results of numerous spectroscopic and photometric studies have revealed the presence of multiple stellar populations in many globular clusters. In this paper we summarize the results of our recent studies on the dynamical evolution of multiple-population clusters, the implications of the structural properties of multiple-population clusters for the evolution of binary stars, and the possible contribution of globular clusters to the assembly of the Galactic halo.

Keywords. (Galaxy:) globular clusters: general, stellar dynamics, methods: n-body simulations

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The discovery of multiple stellar populations in globular clusters (see e.g. Gratton *et al.* 2012 and references therein for a recent review) is extremely important for all the aspects of globular cluster formation and evolution.

In D'Ercole *et al.* (2008), we have studied the formation and dynamical evolution of multiple populations in globular cluster by means of hydrodynamical and N-body simulations. In our model second generation (SG) stars form from the ejecta of first generation (FG) AGB stars. Our simulations show that the AGB ejecta form a cooling flow and rapidly collect in the innermost regions of the cluster, forming a SG stellar subsystem segregated in the FG cluster inner regions. In order to form the numbers of SG stars observed today, the FG cluster must have been initially much more massive than it is now, and it must have been initially dominated by the FG population. By means of N-body simulations, in D'Ercole *et al.* (2008) we have shown that the early expansion triggered by the loss of SN II ejecta leads to the strong preferential loss of FG stars while, the inner SG stars, are unscathed by this early evolution: during this early evolutionary phase the cluster evolves from a configuration in which FG stars dominate to one with a similar number of of FG and SG stars (or even one in which the SG stars are now the dominant population), as observed in several Galactic globular clusters (see e.g. Carretta *et al.* 2009a,b). In our recent studies, we have explored the dynamical evolution of multiple-population clusters, the implications of the structural properties of multiple-population clusters for the evolution of a cluster binary star population and the connection between SG stars in clusters and in the Galactic halo.

• The structural properties of multiple population clusters differ from those of simple Plummer or King models usually adopted in the study of the dynamical evolution of globular clusters. In Vesperini *et al.* (2011), we have explored the implications of the presence of a concentrated SG subcluster on the evolution of FG and SG binary stars. Binary stars are extremely important for different aspects of the evolution of globular clusters and their stellar content (see e.g. Heggie & Hut 2003 for a review) and it is

important to understand their evolution in multiple-population clusters. Our study shows that in multiple-population clusters, SG binaries are preferentially disrupted and that, more generally, binary disruption is enhanced compared to a standard cluster with similar mass and size but without an inner SG subsystem (see D'Orazi *et al.* 2010 for the first observational results indicating the preferential disruption of SG binaries).

• As a cluster evolves and enters the phase dominated by two-body relaxation some SG stars may escape and populate the Galactic halo. In Vesperini *et al.* (2010) we have carried out a study to estimate the number of SG stars that may have formed in Galactic globular clusters as a function of the cluster mass, structural properties and stellar initial mass function and the fraction of the Galactic halo composed of SG stars escaped from clusters. Our models show that the fraction of SG stars in clusters and in the Galactic halo can constrain both models for the formation and dynamical evolution of multiple stellar generations in globular clusters and the globular cluster contribution to the formation history of the Galactic halo.

• In Vesperini *et al.* (2012) we have carried out a survey of N-body simulations to explore the long-term evolution of multiple-population clusters. In particular we have focussed our attention on the study of the time scales and the dynamics of the spatial mixing of FG and SG stars. We have shown that the time scale of FG-SG complete mixing depends on the SG initial concentration but in all cases complete mixing is expected only for clusters in the advanced phases of their dynamical evolution. Unless a cluster is completely mixed, the SG-to-FG number ratio at a given distance from the cluster center is in general different from the global value. Our simulations indicate that, so long as mixing is not complete, the local value of N_{SG}/N_{FG} measured at $R \approx (1-2)R_h$ (where R_h is the cluster half-mass radius) is approximately equal to the global SG-to-FG number ratio.

Our simulations suggest that in many Galactic globular clusters, SG stars should still be more spatially concentrated than FG stars.

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