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Globular cluster contributions to Galactic halo assembly

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Abstract. I discuss a search for red giant stars in the Galactic halo with light-element abundances similar to second-generation globular cluster stars, and discuss the implications of such a population for globular cluster formation models and the balance between *in situ* star formation and accretion for the assembly of the Galactic halo.

Keywords. Galaxy:formation, Galaxy:halo, Galaxy:stellar content, globular clusters:general

1. Introduction

We presently interpret the C-N, O-Na and Mg-Al abundance anticorrelations in globular cluster (GC) stars as a result of two-generation star formation and stellar-mode (i.e., supernova-free) chemical feedback (e.g., Carretta *et al.* 2010; D'Ercole *et al.* 2008). The present-day ratio of second- to first-generation stars in GCs is roughly 1:1, which leads to what is known as the "mass budget problem": there is simply not enough mass in stellar winds from the first generation to produce an equally massive second generation. Proposed solutions have included a top-heavy IMF for the first generation (Decressin *et al.* 2007) and a truncated mass function for the second generation (D'Ercole *et al.* 2008), but currently favored models require that the first generation was originally more massive (by a factor of 10-20) than it currently is. These massive GC formation models then require that the excess first-generation stars be preferentially removed from the cluster to reduce the ratio of second- to first-generation stars to its present-day level.

There are GCs that are currently losing stars to the halo field through extended tidal tails (e.g., Palomar 5, Odenkirchen *et al.* 2003; NGC 5466, Belokurov *et al.* 2006), and there is a theoretical expectation that many more GCs should have dissolved at earlier times as a result of tidal interactions with the Galaxy, internal 2-body interactions, and stellar evolution (Gnedin & Ostriker 1997). If these globular clusters contained second-generation stars at the point of dissolution, then some fraction of halo field stars should carry the second-generation light-element abundance pattern.

2. Globular cluster migrants in the halo field

To look for halo field stars with second-generation abundances, Martell & Grebel (2010) and Martell *et al.* (2011) searched the Sloan Digital Sky Survey (SDSS) SEGUE and SEGUE-2 low-resolution spectroscopic databases, respectively. Selecting red giants with $-1.8 \leqslant [Fe/H] \leqslant -1.0$, reasonably well-determined stellar parameters and clean spectra, they identified a total of 2519 halo giants, 65 of which ($\sim 2.5\%$) appear to have second-generation carbon and nitrogen abudances. For these stars, the 3883Å CN band is strong and the 4320Å CH G-band is weak, relative to other field stars at similar metallicity and evolutionary phase.

Ongoing work (Carollo *et al.*, in prep.) is finding that these CN-strong field giants, presumably second-generation globular cluster stars that have been lost to the halo, have orbits and kinematics consistent with the inner halo population (Carollo *et al.* 2007; 2010). In that work, we are also finding that globular clusters with proper motion measurements available in the literature† have orbits and kinematics similar to the inner halo population, making them a reasonable potential source for *in situ* formation of the inner halo.

3. Conclusions

The fraction of stars in the Galactic halo with light-element abundances similar to second-generation globular cluster stars is small, roughly 2.5%, but high-mass models for globular cluster formation require that they should be accompanied by several times as many first-generation stars, chemically indistinguishable from halo stars that formed outside GCs. This implies that globular clusters, as a major site of star formation 12 Gyr ago, are a significant contributor to Galactic halo assembly.

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† Available at http://www.astro.yale.edu/dana/gc.html