EPJ Web of Conferences **19**, 03007 (2012)
DOI: 10.1051/epjconf/20121903007
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Two views of globular cluster stars in the Galactic halo

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Abstract. In [1] we reported the discovery in the Sloan Digital Sky Survey-II/SEGUE spectroscopic database of a small subset of halo red giants, 2.5%, with CN and CH band strengths indicative of globular-cluster-like carbon and nitrogen abundances. Because the formation of stars with unusual light-element abundances is thought to be restricted to high-density environments like globular clusters, this result has strong implications for both cluster formation processes and the assembly history of the Galactic halo. Here we discuss two efforts to expand upon that work.

1. INTRODUCTION

Globular clusters in the Milky Way all contain clear light-element abundance variations (e.g., [2–5]). The typical pattern is C-N, O-Na and Mg-Al anticorrelations, with roughly half of the stars having scaled-Solar abundances and half showing a range of depletions in C, O and Mg and enhancements in N, Na and Al. This pattern is presently interpreted as a sign that stars in globular clusters are formed in two closely spaced generations. The variations in light-element abundance pattern (and the lack of α-element or iron enhancement between the two generations) are then thought to be a result of chemical feedback only in the light elements, through the retention and recycling of winds from AGB stars (e.g., [6]), rapidly rotating massive stars (e.g., [7]), lossy mass transfer in massive binary systems (e.g., [8]) or some combination of these sources.

Although light-element abundance variations are found in all Galactic globular clusters, they have not been found in open clusters (e.g., [9–11]), lending weight to the idea that the high density of early globular clusters permitted a partial self-enrichment, and indicating that unusual light-element abundances can be used to identify stars that originally formed within globular clusters, even after those clusters have been disrupted through tidal interactions with the Galaxy or evaporated through internal two-body interactions.

2. CLUSTER-ORIGINATING STARS IN SDSS DATA

The search for stars with globular cluster-like light-element abundances was extended by [12] into the SEGUE-2 data set ([13]), a low-resolution spectroscopic survey based on SDSS photometry that targeted red giant stars to larger distances than the original SEGUE survey ([14]). The authors' main goal was to search for trends between Galactocentric distance and the frequency of stars originating in globular clusters. They confirmed the overall result of [1], finding that 16 of the 561 halo red giant in their sample, roughly 3%, were CN-strong and CH-weak relative to the typical star at fixed metallicity and evolutionary phase, indicating depleted carbon and enhanced nitrogen abundance. They also found

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Article available at http://www.epj-conferences.org or http://dx.doi.org/10.1051/epjconf/20121903007

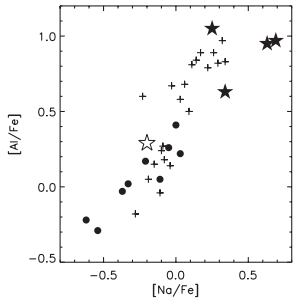

Figure 1. Preliminary sodium and aluminium abundances from our high-resolution followup observations appear to support the claim that CN-strong halo giants carry the full globular cluster-like light-element abundance pattern.

that the CN-strong stars are slightly more centrally concentrated in their sample than the CN-normal stars, with very few CN-strong stars found beyond a Galactocentric distance of 30 kpc. There are several recent theoretical models of galaxy formation (e.g., [15, 16]) that predict two-population halos in spiral galaxies, with the inner halo formed mainly *in situ* and the outer halo formed primarily through accretion of satellites. If this result can be confirmed in future surveys of Galactic chemodynamics, it will implicate globular clusters as an important site of star formation in the early Galaxy.

3. THE FULL LIGHT-ELEMENT ABUNDANCE PATTERN

High-resolution spectroscopic followup observations of the CN-strong SEGUE stars has been underway since early 2010, using the High-Resolution Spectrograph ([17]) on the Hobby-Eberly Telescope at McDonald Observatory and the HIRES spectrograph ([18]) at Keck Observatory (Martell, Shetrone & Lai 2012, in prep). A total of 29 CN-strong stars selected from [1] have been observed at resolutions between $\Delta\lambda/\lambda$ of 15,000 and 30,000, along with 16 CN-normal stars, also from [1], which were observed as a control set. Analysis of the spectra is ongoing, and the preliminary results are promising. Figure 1 shows sodium and aluminium abundances for four moderate-metallicity CN-strong stars (filled stars) and one CN-normal star (open star) from our followup data obtained at HET, along with comparison stars of similar metallicity: red giants in the globular cluster M3 (crosses, data from [19]) and field giants with metallicity similar to M3 (filled circles, data from [20]). While the M3 stars cover a wide, correlated range in sodium and aluminium abundance, the field stars are restricted to lower [Na/Fe] and [Al/Fe] abundances. The CN-normal field star from our new observations falls together with the other field stars at the low-abundance end of the sequence, and the CN-strong stars all fall at the high-abundance end of the sequence, indicating that the CN-CH selection employed in [1] and [12] is effective for identifying stars with the full anomalous light-element abundance pattern from C through Al.

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