Star clusters: basic galactic building blocks
Proceedings IAU Symposium No. 266, 2009
R. de Grijs & J. R. D. Lépine, eds.

doi:10.1017/S1743921309991001

Chemical abundances in tidally disrupted globular clusters

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Abstract. We present abundance measurements in the tidally disrupted globular cluster NGC 6712. In this cluster, there are large star-to-star variations of the light elements C, N, O, F and Na. While such abundance variations are seen in every well-studied globular cluster, they are not found in field stars and indicate that clusters like NGC 6712 cannot provide many field stars and/or field stars do not form in environments with chemical-enrichment histories like those of NGC 6712. Preliminary analysis of NGC 5466, another tidally disrupted cluster, suggests little (if any) abundance variation for O and Na and the abundance ratios [X/Fe] are comparable to field stars at the same metallicity. Therefore, globular clusters like NGC 5466 may have been Galactic building blocks.

Keywords. Galaxy: abundances, globular clusters: individual (NGC 5466, NGC 6712), stars: abundances

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Globular clusters are the oldest Galactic objects for which reliable ages can be obtained (e.g., Gratton *et al.* 2003) and have long been regarded to be the first bound systems to have formed in the protogalactic era (Peebles & Dicke 1968). As such, they have witnessed the subsequent formation and evolution of our Galaxy. However, were globular clusters innocent bystanders to the chaotic hierarchical assembly of our Galaxy, or were they active, albeit possibly minor, participants? After all, the vast majority of stars are believed to form in clusters (e.g., Lada & Lada 2003).

Several globular clusters are currently experiencing tidal disruption. SDSS images have revealed large tidal tails near Pal 5 (Odenkirchen *et al.* 2001) and NGC 5466 (Belokurov *et al.* 2006). Additional evidence for tidal stripping comes from flat mass functions which indicate significant depletions of low-mass stars, presumably stripped by the Galactic tidal field. [At this meeting, Balbinot *et al.* (2009) presented another globular cluster, NGC 6642, whose mass function shows evidence for tidal disruption.]

Chemical-abundance analyses provide a powerful constraint upon the fraction of field stars that may come from globular clusters and/or the types of globular clusters that may populate the field. Every well-studied Galactic globular cluster, including Pal 5 (Smith *et al.* 2002), shows large star-to-star abundance variations for the light elements from C to Al (e.g., Gratton *et al.* 2004; Yong *et al.* 2008b; Meléndez & Cohen 2009). However, such abundance variations have not yet been found in field stars.

NGC 6712 is the only cluster whose mass function decreases with decreasing mass (de Marchi *et al.* 2000). With an orbit penetrating deep into the bulge (Dinescu *et al.* 1999), tidal forces have stripped a large fraction of low-mass stars. Using the high-resolution infrared spectrograph Phoenix on the *Gemini South* telescope, we measured the abundances of C, N, O, F, Na and Fe (Yong *et al.* 2008a).

Within our sample of seven bright giants (all have radial velocities and Fe abundances consistent with cluster membership), we detect large star-to-star abundance variations for C, N, O, F and Na (see Figure 1). Such abundance patterns are not found in field stars and therefore clusters like NGC 6712 and Palomar 5 cannot provide many field stars and/or field stars do not form in environments with chemical-enrichment histories like those of NGC 6712 and Palomar 5.

NGC 6712 is only the second cluster in which F has been observed in more than two stars and both clusters show F abundance variations which may be produced in asymptotic giant branch stars with masses $M > 5$ $M_{\odot}$ (Smith *et al.* 2005; Karakas *et al.* 2008). Indeed, within the limited samples, the fluorine abundances in all globular cluster stars are considerably lower than in field and bulge stars at the same metallicity (see Figure 2), which highlights additional chemical differences between the field and cluster environment.

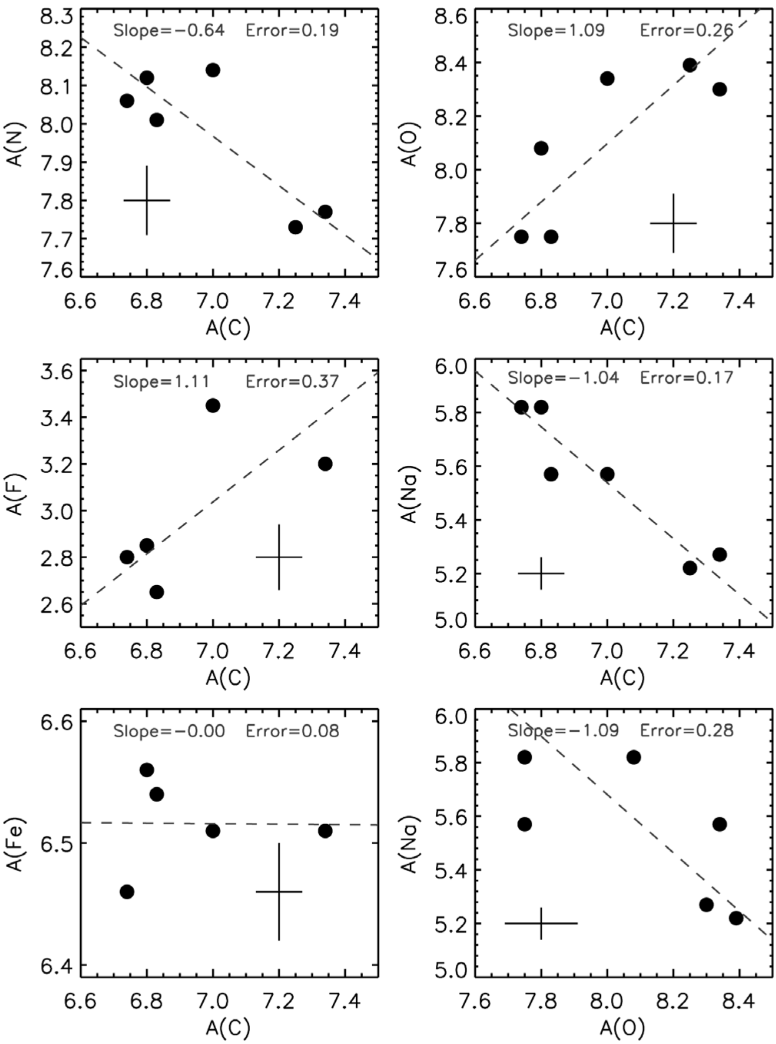

Figure 1. Elemental abundances A(X) versus A(C) as well as A(Na) versus A(O) *(bottom right panel)*. A representative error bar is shown. The dashed line is the linear least-squares fit to the data (slope and associated error are included).

https://doi.org/10.1017/S1743921309991001 Published online by Cambridge University Press

The chemical abundances measured in this cluster offer the intriguing prospect of allowing us to estimate the initial mass of this cluster, and, therefore, the fraction of mass lost through tidal stripping. Carretta (2006) found a correlation between the amplitude of the abundance variations (actually, the interquartile range of, e.g., [O/Fe], [Na/Fe] and/or [O/Na] and the absolute magnitude). Based on the interquartile range of [O/Na], we tentatively confirm the calculations by Takahashi & Portegies Zwart (2000), which indicate that NGC 6712 was once one of the most massive clusters to have formed in our Galaxy.

Of great interest would be the chemical analysis of additional globular clusters that show evidence for tidal disruption to search for a cluster in which there are no light-element abundance variations. Equally important would be to expand the search for

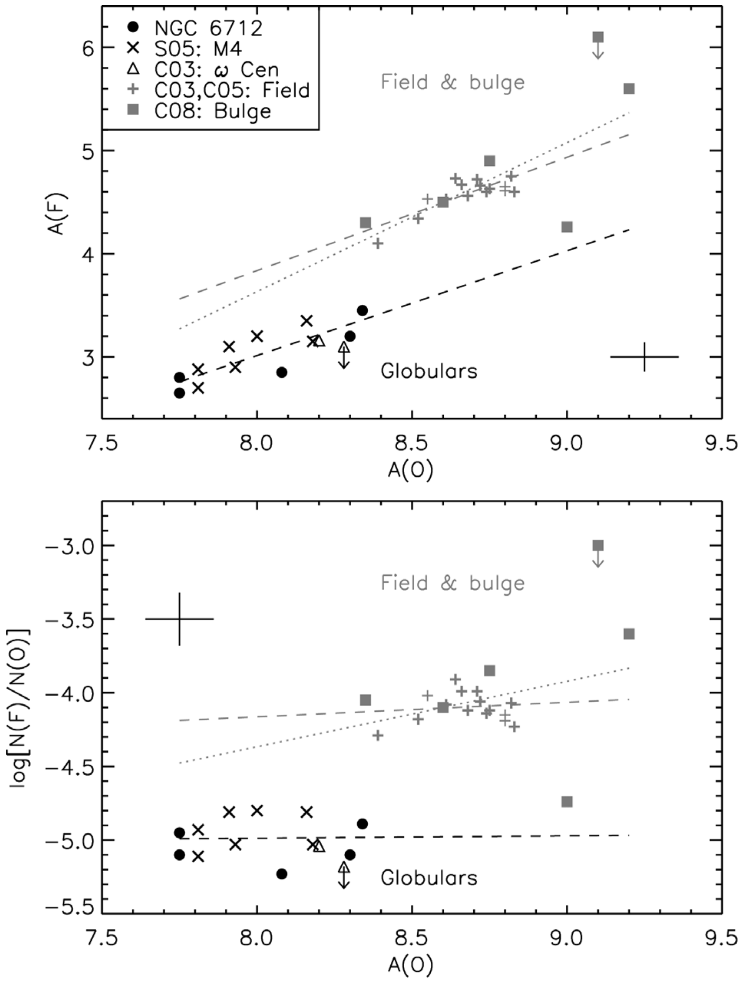

Figure 2. A(F) versus A(O) (top) and log[N(F)/N(O)] versus A(O) (bottom). NGC 6712 (black circles), M4 (black crosses: Smith *et al.* 2005), ω Cen (black triangles: Cunha *et al.* 2003), bulge stars (red squares: Cunha *et al.* 2008) and field stars (red plus signs: Cunha *et al.* 2003; Cunha & Smith 2005) are shown. The dashed lines are the linear least-squares fits to the field and bulge, and globular cluster data, respectively (excluding upper limits). The dotted line is the fit to the field and bulge data excluding the upper limits and the bulge star with $A(\mathrm{O}) = 9.0$.

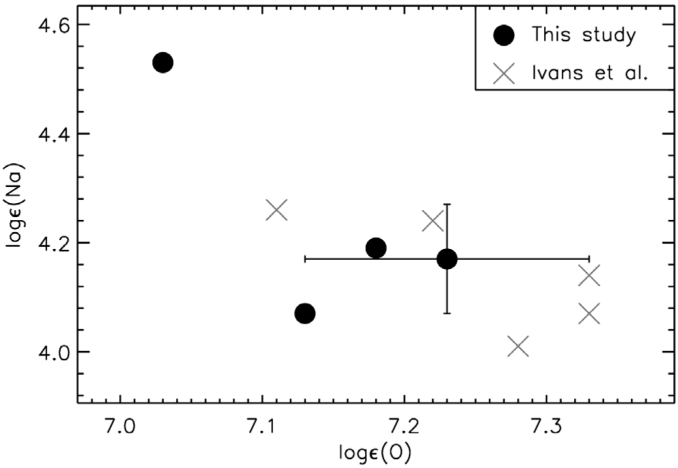

Figure 3. Preliminary abundances of Na versus O in NGC 5466.

field stars which exhibit the globular cluster light-element abundance patterns. These endeavors will enhance our understanding of the formation and evolution of our Galaxy.

To this end, we present preliminary results for NGC 5466, a tidally disrupted globular cluster. Our sample of nine stars includes five stars analysed by I. Ivans (priv. comm.). Excluding one O-rich, Na-poor star, the remaining stars have O and Na abundance measurements that may be regarded as constant within the measurement uncertainties (see Figure 3). All stars lie within the range exhibited by field stars at the cluster's metallicity. Therefore, clusters like NGC 5466 may have contributed to building the halo.

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