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Multiple stellar populations in the massive clusters M22 and Omega Centauri

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Abstract. An intriguing discovery in the field of multiple stellar populations in globular clusters is that some of them show internal variations in the bulk of the heavy-element content. I summarize the chemical properties of one of these clusters, M22, in comparison with the most extreme ω Centauri, underlying the analogies and differences between the two objects.

Keywords. stars: abundances, globular clusters: individual (M22, ω Centauri).

1. Introduction

Since the '80s we know that light elements show peculiar patterns in globular clusters (GCs). On the other hand, variations in heavier elements were considered to be a trait of more massive systems capable to retain SN fast ejecta. In this respect the most massive Galactic GC ω Cen was always considered a peculiarity. In fact, to account for its well known huge metallicity variations, it has even been suggested that ω Cen is the remnant of a tidally disrupted dwarf galaxy rather than a *real* GC.

Surprisingly, recent discoveries have revealed that some GCs, besides ω Cen, have variations also in the bulk heavy element content, in analogy with more massive systems. Differently from the simple *normal GCs* that do not show evidence for SN-based self enrichment, in these objects successive generation(s) may need to be invoked, with SNe also playing a role in the pollution of intra-cluster medium.

Among these *anomalous* GCs, M22 is the first discovered (Marino *et al.* 2009, hereafter M09; Da Costa *et al.* 2009) and surely the one whose spectroscopic features more closely resemble ω Cen (Da Costa & Marino 2011).

2. M22 versus ω Centauri

The most striking similarity between M22 and ω Cen is the internal variation in the overall metallicity. In M22, M09 and Marino *et al.* (2011a, hereafter M11a) obtain a total metallicity spread of more than a factor of two: $-1.97 \leqslant$ [Fe/H] $\leqslant -1.57$, a range that cannot be explained by observational uncertainties. Note that, although metallicity variations are present in both clusters, in ω Cen the range in [Fe/H] is more than a factor of 20 larger, with stars from [Fe/H] ≈ -1.90 to [Fe/H] ≈ -0.60.

In addition to this, the abundance distribution for elements mainly produced in the slow (s) neutron-capture processes is clearly bimodal in M22 (M09, M11a). The two stellar groups with different s element content (s-rich and s-poor groups) are also characterized by: *(ii)* a mean different metallicity (M09); *(ii)* a mean different C+N+O content (M11a, Alves-Brito *et al.* 2012); *(iii)* in both groups internal variations in elements involved in the high temperature H-burning are present (M11a), so that each group individually traces the (anti)correlations in light elements found in *normal* GCs; *(iv)* on

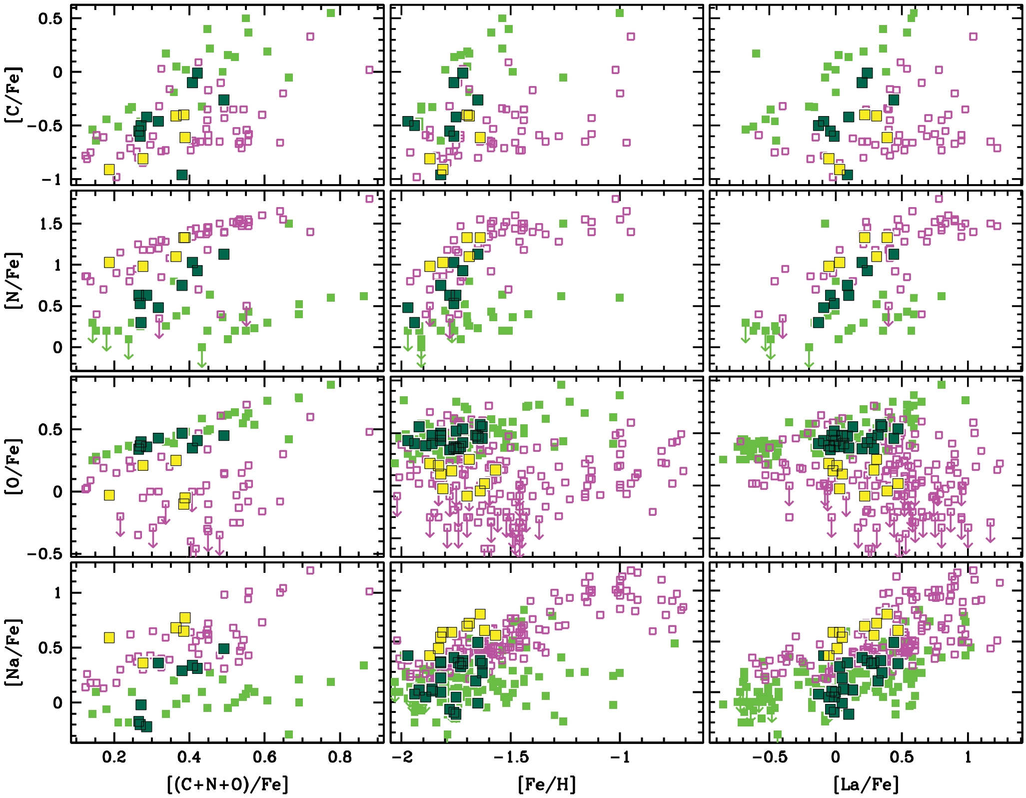

Figure 1. C, N, O Na relative to Fe as a function of [CNO/Fe], [Fe/H], and [La/Fe] for M22 and ω Cen stars. Dark-green and yellow points are the Na-poor and Na-rich stars in M22, and light-green and magenta points are the Na-poor and Na-rich stars in ω Cen, respectively.

the photometric side, M22 shows a split sub-giant branch (Piotto *et al.* 2012), whose sequences correspond to the two s groups (Marino *et al.* 2012a).

The properties observed in M22 are also present in ω Cen, but again, in this latter they are much more extreme. In Figure 1 a collection of chemical abundances for M22 (from M09 and M11a) and ω Cen (Marino *et al.* 2011b, 2012b, hereafter M11b, M12b) is shown. In both clusters, stars have been divided into two groups on the basis of their position along the O-Na anti-correlation (see M12b for details). Note that the separation of different stellar groups on the basis of their light-element abundances is just a possibility. Alternatively, the separation in stellar groups could be explored on the basis of metallicity or s content (as in M11a, and M11b). An inspection of Figure 1 immediately gives an idea of how more extreme are the chemical variations in ω Cen, and, at the same time, how similar are these objects in terms of chemical patterns: *(i)* all the p-capture elements (on the y-axis) have similar trends as a function of the CNO, Fe and s element La; *(ii)* Na-poor and Na-rich stars separately show similar patterns in the two clusters.

The most natural development of these findings is to understand where these objects formed. The analogies with ω Cen, considered the possible relict of a dwarf galaxy, suggest the fascinating idea that also M22 could be the surviving nuclei of more massive system.

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