IS PALOMAR 1 REALLY ASSOCIATED WITH THE CANIS MAJOR OVERDENSITY?

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Abstract. It has recently been suggested that the peculiar cluster Pal 1 is associated to the Canis Major dwarf galaxy, which existence is still at the center of a debate. Our first measurement of the cluster's chemical abundance ratios allows us to examine this association and to advance further in the clarification of Pal 1 possible origin.

1 Introduction

With an age of ~ 8 Gyr and a metallicity $[Fe/H] \simeq -0.6$, Pal 1 does not fit the age-metallicity relation (AMR) of classical old-halo globular clusters (Rosenberg et al. 1998a, 1998b). It is compatible with the AMR of younger globulars, which is also similar to that of the Sgr dwarf spheroidal (dSph) galaxy (Siegel et al. 2007). The putative Canis Major dwarf was also suggested to have an AMR similar to that of Sgr (Forbes & Bridges 2010), and Pal1 lies close to the CMa orbit in phase space (Martin et al. 2004). The AMRs shown in Fig. 1 (left panel) define a trend, with higher mass galaxies having larger gas consumption rates $d\mu/dt$. Lee I $(\sim 2 \times 10^6 M_{\odot})$, Mateo 1998) has a rate smaller than that of Sgr $(\gtrsim 10^9 M_{\odot})$, Jiang & Binney 2000), whose rate is, in turn, smaller than that of the (proto) Galaxy. The graph therefore suggests that Pal 1 was created in a galaxy with a mass similar to that of Sgr. If Sgr and CMa share a similar AMR, then Fig. 1 would suggest that they also have similar masses and star formation (SF) efficiencies, and presumably also similar abundance ratios, which should be reflected in the Pal 1 ratios, most notably in the α -elements. To check this possibility, these ratios were measured using a high-resolution spectrum of star Pal 1-I (see Rosenberg et

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Fig. 1. Left panel – The filled and open diamonds represent the AMR of old- and younghalo globular clusters from Marin-Franch et al. (2009), while open circles represent the Leo I AMR from Gullieuszik et al. (2009). The curves are three closed-box models with a yield $y = Z_{\odot}/2$ and different gas consumption rates $d\mu/dt$, where $\mu = M_{\text{gas}}/M_{\text{tot}}$: $d\mu/dt = 10$ for old clusters, $d\mu/dt = 1.2$ for young clusters, and $d\mu/dt = 0.2$ for Leo I. The dashed curve corresponds to the AMR of the Sgr dSph (Siegel et al. 2007). The encircled dot represents Pal 1. **Right panel** – Pall-I (big empty red star) α -element abundance ratios are presented together with Sagittarius dSph stars (grey shaded area) from Sbordone et al. (2007), and stars in the GCs Pal 12 (big open blue triangle) and Ter 7 (big blue asterisk) from Cohen (2004) and Sbordone et al. (2007), respectively. Stars in the CMa overdensity region in the background of the open cluster NGC 2477 are plotted as big open circles (Sbordone et al. 2005).

al. 1998b) obtained with HDS@SUBARU (Monaco et al., 2010, A&A, in press; arXiv1011.0123).

2 Abundance ratios of Pal 1

The α -element abundance ratios of Pal 1 are presented in Fig. 1 (right panel) together with those of Sgr stars and its associated clusters Pal 12 and Ter 7 (see Cohen 2004 and Sbordone et al. 2007), and of stars in the CMa overdensity region (Sbordone et al. 2005). Abundances of all other analyzed elements are presented in Monaco et al. The most metal-poor among CMa stars has an iron content similar to that of Pal 1-I and the chemical composition of the two objects is also similar. In general, Sbordone et al. (2005) suggested that the CMa structure has a level of chemical processing compatible with that of the Galactic disk, true also for Pal 1. An association of the cluster to CMa might then be possible¹. The

¹It should be noted, however, that the low Galactic latitude of CMa makes contamination from the disk itself a relevant issue, and make it difficult to unambiguously assign membership

abundance ratios of Sgr are instead quite different. While the abundance of silicon is compatible to that of Sgr, the rest of α -elements (Fig. 1), iron-peak and light element abundance ratios (see Monaco et al. 2010) are distinctively different.

In conclusion, Pal 1 chemical abundance pattern is similar to that of CMa (albeit based on one star only) but also to Galactic open clusters (OCs). The cluster might therefore be associated to CMa, although the separation between CMa and the Galactic disk remains an open question.

Contrary to the expectations of the Introduction, CMa and Sgr have different abundance patterns despite having the same AMR. Sgr does have an α -element pattern similar to those of other dSph of the Local Group (Monaco et al. 2005; Sbordone et al. 2007), so one solution of this puzzle might be that CMa is not really an independent entity, and the mass-SF efficiency relation does not apply to it (Momany et al. 2006).

Palomar 1 might then be a GC which experienced a peculiar chemical evolution or an OC ejected from the Galactic disk, which high concentration and flat mass function (see Rosenberg et al. 1998b) would be the result of its peculiar dynamical evolution. Only a reconstruction of the cluster's orbit would permit discriminating between the two possibilities. Because radial velocities and positions are not sufficient to claim a common orbit, a measurement of proper motions is needed to break degeneracies.

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