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The Nature of the Triangulum-Andromeda Stellar Structures

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Abstract. The outer stellar halo is home to a number of substructures that are remnants of former interactions of the Galaxy with its dwarf satellites. Triangulum-Andromeda (TriAnd) is one of these halo substructures, found as a debris cloud by Rocha-Pinto *et al.*, (2004) using 2MASS M giants. Would be these structures related to dwarf galaxies or to the galactic disk? To uncover the nature of these stars we performed a high-resolution spectroscopic study (R = 40,000) along with a kinematic analysis using Gaia data. We determined the atmospheric parameters and chemical abundances of Ca and Mg for the 13 TriAnd candidate stars along with their respective orbits. Our results indicate that the TriAnd stars analyzed have a galactic nature but that these stars are not from the local thin disk.

Keywords. Galaxy: structure, Galaxy: outer disk, stars: chemical abundances, stars: kinematic

1. Introduction

The Milky Way was formed in a complex chain of physical processes involving dissipative gravitational collapse, gas flows, and galactic mergers. Stellar overdensities are structures that can help us trace this Galaxy formation history. Recently, the TriAnd overdensity is one of the stellar overdensities that has aroused great interest due to its unknown nature. Initially thought to be a vestige of a dwarf galaxy (Chou et al. 2010), the nature of the TriAnd overdensity is now connected to the galactic disk (Hayes *et al.* 2018; Bergemann *et al.* 2018), which a priori was not expected because of its high distance from the galactic plane. Bergemann *et al.* (2018) concluded that besides being from the disk such overdensity would have a chemical pattern of the thin disk. Later on Hayes *et al.* (2018) using SDSS IV - APOGEE data (Majewski *et al.* 2017) concluded that the overdensity of TriAnd stars would indeed be an extension of the disk for lower metallicities. In this contribution, we present our first results from a spectral study of stars in the TriAnd region using data obtained from the 8m telescope (Gemini-North) and the high-resolution spectrograph GRACES.

2. The Sample and methodology

Candidate TriAnd stars were initially selected using a color criterion in the J-H vs. J-K diagram that segregates M giants from M dwarfs (Rocha-Pinto *et al.* 2004). Recently, Perottoni *et al.* (2018) uncovered several scattered dense excesses of main sequence stars

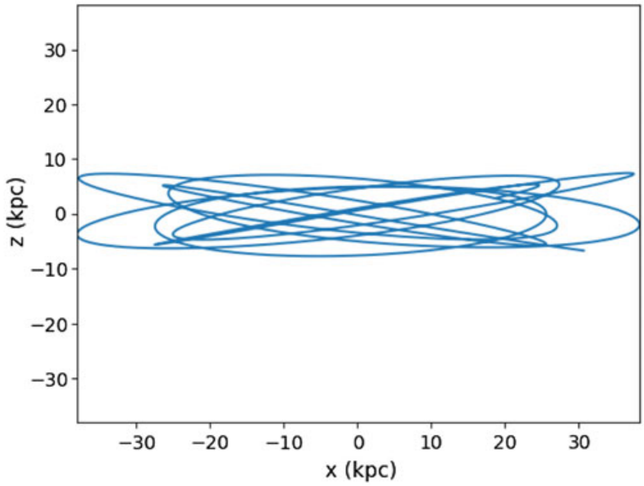

Figure 1. Orbit of one of the sample TriAnd stars in the xz plane using Gaia data. The other stars of TriAnd analyzed have similar orbits.

situated in the TriAnd region. At least two of these excesses may represent new, not previously known, stellar structures, and one of them resembles a stellar stream. A similar discovery was made by Martin *et al.* (2014) in a smaller area around M 31. The better photometry in Martin *et al.* (2014) data points to a likely mix of stellar populations in these debris.

Our sample consists of 13 TriAnd candidate stars. We selected our final sample from the densest regions in the Perottoni *et al.* (2018) map. The targets were observed using the instrument GRACES (Tollestrup *et al.* 2012; Chene *et al.* 2014) coupled to the Gemini North telescope. We used the OPERA pipeline (Martioli *et al.* 2012) and the IRAF code to reduce the spectra. The final spectra have typical signal-to-noise ratios of ≈ 70-80 at 6000Å. Spectral analysis was performed in LTE using the MOOG code (Sneden 1973) and MARCS model atmospheres (Gustafsson *et al.* 2008). The unique solution to the atmospheric parameters of the stars was determined using the excitation and ionization equilibrium, and the independence of the equivalent width with the abundance of the FeI/II lines. Chemical abundances were determined using equivalent widths. NLTE corrections were made for elements in which such corrections were not negligible.

3. Discussion and conclusion

The TriAnd stars of our sample present kinematic properties of the disk (Figure 1). However, the metallicities of these stars ($-1.36 \leqslant$[Fe/H]$\leqslant -0.8$) are overall much more metal-poor and do not overlap with the metallicities of the few open clusters in the outer disk ([Fe/H]≈-0.5 dex, Yong *et al.* 2012). We also note that the TriAnd stars are at higher Z and it is possible that these stars were moved due to oscillations or kicked out from the disk plane (Gómez *et al.* 2013; Bergemann *et al.* 2018) and one would assume that at 8-10 Gyr ago the disk had such low metallicity stars.

In figure 2 we compare our results of chemical abundances (red circles) with results from other TriAnd stars in the literature (Bergemann *et al.* 2018, red open circles, and Hayes *et al.* 2018, red open circles), disk stars (Bensby *et al.* 2014), and some dwarf galaxies stars: Fornax (Shetrone *et al.* 2003, Letarte 2007; blue crosses), Sagitrius (Monaco *et al.* 2005, Sbordone *et al.* 2007; orange stars), Sculptor (Shetrone *et al.* 2003, Geisler *et al.* 2005; green triangles) and Carina (Shetrone *et al.* 2003, Koch *et al.* 2008; purple squares).

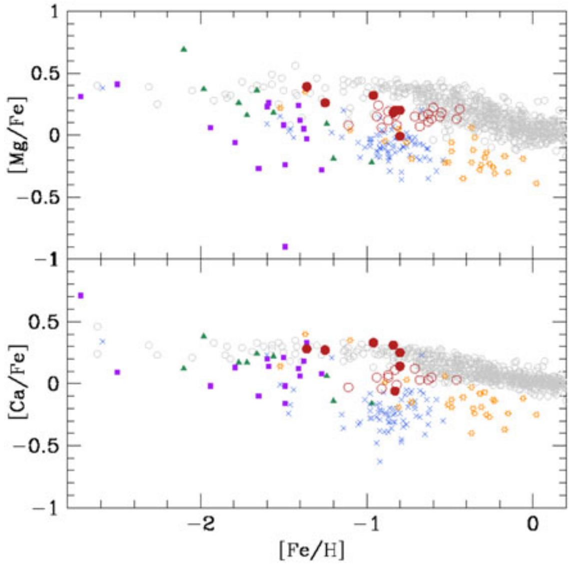

Figure 2. [Mg/Fe] and [Ca/Fe] ratios versus [Fe/H] of our sample compared with literature results.

Our sample of stars presents an abundance of the alpha-elements Mg and Ca that is similar to that of disk stars and does not overalp with the dwarf spheroidals. However, in terms of the metallicity (Fe), the TriAnd stars do not overlap with the local thin disk.

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