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Evidences of extragalactic origin and planet engulfment in the metal-poor binary HD 134439/HD 134440.

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Abstract. With high resolution (R∼ 72000), high S/N ratio (S/N∼ 250) HDS/Subaru spectra we revisited the abundance pattern of the HD 134439/ HD 134440 binary pair. We employed the line-by-line differential technique to achieve very high precision abundances on 22 different elements. We compare the abundance patterns to a well-known benchmark halo star (HD 103095), to dwarf spheroidal galaxies, and to the low and high-alpha halo stars from Nissen & Schuster (2010). We confirm that the abundance pattern of these stars closely resembles stars from a foreign galaxy and find a peculiar abundance difference between the stars in all elements analyzed. We propose that the difference in abundance between these binary stars could be explained by the accretion of a planet by one of the components. More details are given in Reggiani & Meléndez (2018).

Resumo. Com espectros de alta resolução (R∼ 72000) e alta razão S/N (S/N∼ 250), reanalisamos o padrão de abundâncias químicas do par de estrelas binárias HD 134439/ HD 134440. Através de uma análise diferencial linha-por-linha obtivemos medidas de alta precisão para 22 elementos químicos. Comparamos nossas abundâncias as de uma estrela padrão do halo interno (HD 103095), a estrelas de galáxias anãs e as populações com alta e baixa razão [α/Fe] de Nissen & Schuster (2010). Confirmamos que o padrão de abundâncias deste par de estrelas pode ser correlacionado a estrelas extragaláticas e também encontramos uma diferença de abundâncias peculiar entre as estrelas binárias. Propusemos que esta diferença pode ser originária do engolimento de um planeta por uma das componentes. Para a análise completa, veja Reggiani & Meléndez (2018).

Keywords. Stars:abundances – Stars: chemically peculiar – Galaxy: halo

1. Introduction

A portion of the galactic halo was accreted from satellite galaxies (Nissen & Schuster 2010; Ramírez et al. 2011; Fishlock et al. 2017), as evidenced by different populations in the galactic halo. Recent studies point that maybe all of the halo stars with enhancement in r-process were accreted from satellite galaxies (Roederer et al. 2018). Analysis of the kinematics of RR Lyrae stars from GAIA show that the inner halo of the Milky Way was formed by the merge of the Milky Way with only one massive satellite galaxy (Iorio & Belokurov 2018). All these scenarios point to extensive stellar populations with distinct chemical patterns in the halo. Using chemical tagging one can expect to distinguish these different patterns and try to shed a light on the birth environment(s) of these stars.

Although we are yet to have the technical capabilities, it is clear that we will be able to detect planets in other galaxies. As planet formation theory evolves it becomes increasingly clearer that it is possible to form planets under low metallicity conditions, although the planets might have to form in close proximity to the stars, with a distance directly related to the stellar metallicity (Johnson & Li 2012). There is also many indications that planet formation can leave a particular imprint on the chemical pattern of its host star (Ramírez et al. 2011; Tucci Maia et al. 2014, 2018; Biazzo et al. 2015; Ramírez et al. 2015; Teske et al. 2016), a pattern that is easier to recognize when we are comparing a star host to a planet to a twin star without any planets.

Two chemically peculiar stars have caught the attention of astronomers, stars HD 134439/134440. They are known both for their high proper motions and also their uncanny abundance pattern, that differs from halo stars as they have much lower abundances of α-elements, suggesting that these stars were accreted from a satellite galaxy (Chen & Zhao 2006; Chen et al. 2014).

A reanalysis of the abundance pattern of these two peculiar stars was published in Reggiani & Meléndez (2018) and here we discuss our main results.

2. Observations and results

High resolution (R∼ 72000) high S/N (S/N∼ 250) spectra of stars HD 134439, HD 134440, and HD 103095 were obtained using the HDS spectrograph at the Subaru telescope and the data were fully reduced using the IRAF package. Using the line-by-line differential abundances, with star HD 103095 used as the standard star, we estimated the chemical pattern of these three stars and compare it to observations of different populations, in the halo of the Milky Way and stellar abundances from satellite galaxies.

In Figure 1 we show an example of the abundances of [Mg,Ca,O/Fe] against [Fe/H]. We see that the binary pair is underabundant when compared to Milky Way stars but their abundances are comparable to stars from satellite galaxies. We also estimated abundances of neutron capture elements [Ba/Y], and they are supersolar, contrary to what is commonly found for stars from the Mily Way. Further evidence come from the Eu measurements of Chen et al. (2014) that, along with our barium, result in both stars being located in a r-process dominant region. From all these evidences we proposed that this pair of stars come from an environment with a pollution history similar to that of the Fornax Galaxy.

In Figure 2 we show that there is a consistent difference between the abundances of these stars of ∼ 0.06 dex, a similar behavior to what was found by Ramírez et al. (2011) and attributed to the ingestion of a planet in one of the analyzed stars. We used a t-test to this set of data, with our mean errors added, and found that the probability of this difference being due to observational

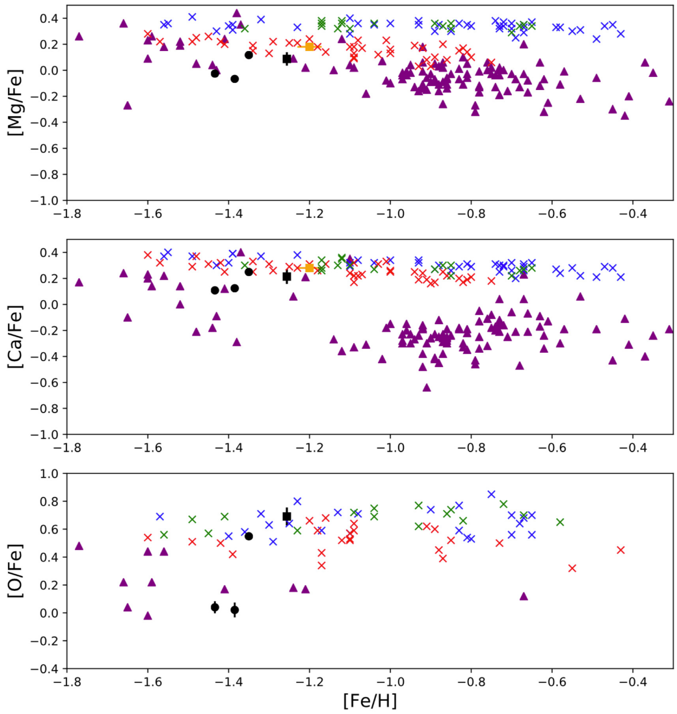

Figure 1. [α/Fe] for our analyzed stars in black dots. The blue and red crosses are the high and low alpha populations of Nissen & Schuster (2010); Ramírez et al. (2012). The triangles are dwarf galaxies stars (Shetrone et al. 2003; Geisler et al. 2005; Monaco et al. 2005; Letarte et al. 2010)

and systematic uncertainties is of the order of 10^{-8}. It is important to further enforce that these are binary stars (confirmed with GAIA in El-Badry & Rix (2018)). Thus, they were born in the same natal cloud and their initial abundance pattern should have been the same, and without any significant difference in their evolutionary stage (they are almost twin stars) an outside process is necessary to explain the abundance differences. Therefore we proposed that a possible explanation for this uncanny difference might be the accretion of a planet. If star HD 134440 accreted a planet with a mass of $M \approx 0.9 M_J$ the increase in photosperic abundance of this star due to this accretion event would explain the observed overabundance.

The full analysis was published in Reggiani & Meléndez (2018).

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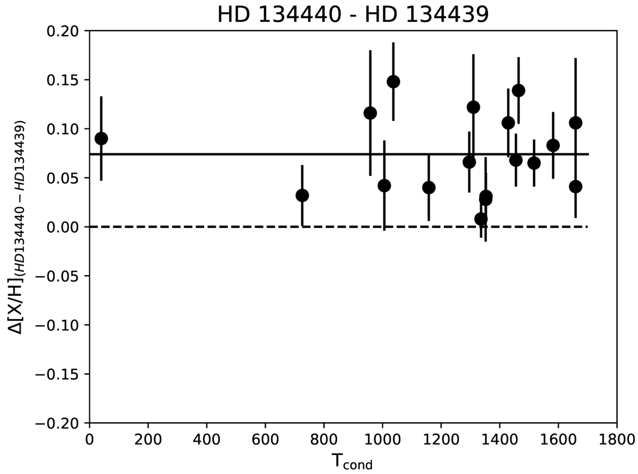

Figure 2. Abundance difference between the stars of the binary pair as a function of the condensation temperature of the elements.

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