From Lithium to Uranium: Elemental Tracers of Early Cosmic Evolution
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Solar Vicinity: Star of Extragalactic Origin

Vladimir A. Marsakov[1] and Tatyana V. Borkova[1]

[1]Spas Reseach Department, Rostov State University of Rossia, Sorge st., 5, 344090, Russia
email: marsakov@ip.rsu.ru, borkova@ip.rsu.ru

Abstract. Using a kinematic criterion reveals stars of extragalactic origin from our sample. We show that the ratios of r- and α-elements in all the accreted stars differ sharply from those in the stars that are genetically associated with the Galaxy. Since the majority of accreted stars of our sample exhibit a significant Eu overabundance relative to Mg, we conclude that the maximum masses of the SN II progenitors outside the Galaxy were much lower than those inside it. We provide evidence that the maximum mass of the SN II progenitors increased in the Galaxy with time simultaneously with the increase in mean metallicity.

Keywords. Stars: abundances, Galaxy: evolution, Galaxy: formation

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1. Introduction

We took the initial sample from the doctoral dissertation by Mashonkina (2003). It includes 77 nearby main sequence F-G stars. All the fundamental physical parameters of the stars and their chemical composition were determined from the spectra with a high spectral resolution and S/N ratio. For all the sample stars, we calculated the distances and spatial velocity components by using modern high-precision astrometric observations. The galactic orbital elements were calculated by using a model of the Galaxy, consisting of a bulge, a disk and a massive halo.

According to the hypothesis of monotonic collapse of the protogalaxy from the halo to the disk suggested by Eggen *et al.* (1962), the stars that are genetically associated with the Galaxy cannot be in retrograde orbits. It follows from the $V_{pec} - \Theta$ diagram in Fig. 1 a that stars with negative rotation velocities, i.e., in retrograde orbits, appear when passing through $V_{pec} \approx 250\,\mathrm{km\,s^{-1}}$. Simultaneously Fig. 1 b demonstrates that all our candidates accreted stars have large dimensions of their orbits, like the globular clusters that are supposed to be accreted by our Galaxy.

The α- and r-elements are generally believed to be synthesised in stars with masses $M \geqslant 10M_{\odot}$ and injected into the interstellar medium by SNe II explosions. Therefore, the most probable [Eu/Mg] ratio for the galactic stars must be equal to zero. However, we see from the figure 2 that accreted stars have mainly lower content of magnesium and all the accreted-halo stars exhibit deviations from the most probable zero [Eu/Mg] ratio.

We separate the five youngest stars from the accreted halo whose isochrone ages turned out compatible with the age of the thin disk. In Fig. 2 a the open crossed circles highlight the anomalously young accreted halo stars. Most of the old accreted halo stars in Fig. 2 b exhibit a significant overabundance, $[Eu/Mg] > 0.2$, with unusual low Mg abundance $[Mg/Fe] < 0.3$ in Fig. 2 a, while almost all metal-poor stars genetically associated with the Galaxy have $[Mg/Fe] > 0.3$. According to current theoretical models, europium is produced mainly in low-mass Type II supernovae (SNe II), while magnesium is synthesised in larger amounts in high-mass SN II progenitors. Therefore the europium overabundance relative to magnesium in all our old accreted-halo stars suggests that the initial mass function of the stars formed outside the protogalaxy was cut-off at high

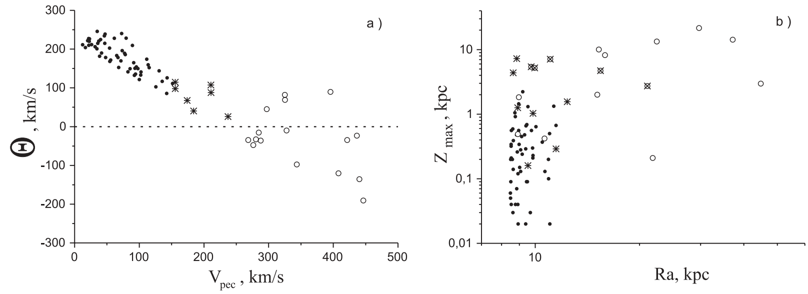

Figure 1. Correlations between the peculiar stellar velocities with respect to the local standard of rest, V_{pec}, and the stellar rotation velocities around the Galactic centre, Θ (a), and between the maximum distances of the points of stellar orbits from the Galactic centre and plane (b); dots are for genetically associated stars, which were born from the single proto-galactic cloud and open circles are accreted stars.

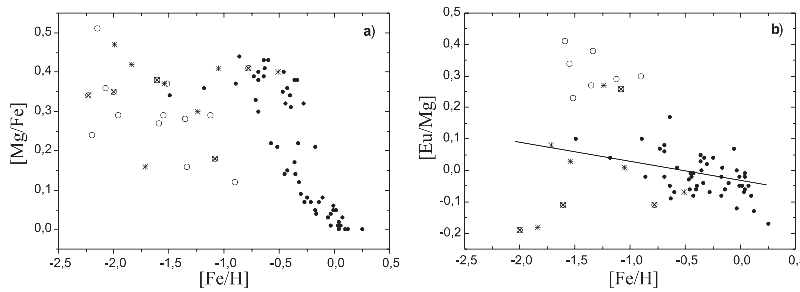

Figure 2. The trend of [Mg/Fe] (a) and [Eu/Mg] (b) with metallicity. The notation is the same as in Fig 1. Crossed circles denote the anomalously young metal-poor stars. The straight line represents an rms regression for the genetically associated stars ($r = 0.4 \pm 0.1$).

masses and began from $M \approx 10 M_{\odot}$. As a result, the yield of α-elements was smaller and r-elements larger than that within the single protogalactic cloud, where the masses of the SN progenitors were larger by several times. The low [α/Fe] ratio for very old accreted metal-poor stars can be more naturally explained by the low masses of the SN II progenitors than by the injection of iron-group elements by SNe Ia, because an Eu underabundance must then be also simultaneously observed in these stars. However, as we see, europium is overabundant in these stars. It thus follows that the low abundance of α-elements alone in stars cannot unambiguously point to slow star formation rate in their parent clouds, as was suggested by Gilmore & Wyse (1998).

Note that all the genetically associated stars show a tendency for [Eu/Mg] to decrease with increasing [Fe/H] at a relatively small spread (the correlation coefficient outside the 3σ limits is nonzero, $r = 0.4 \pm 0.1$). This behaviour suggests that the maximum mass of the SN II progenitors formed inside the Galaxy increases with metallicity (and time).

More detail description of the result can be found in paper Borkova, T.V., & Marsakov, V.A., (2004).

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