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Age-Metallicity Relation in Solar Vicinity from RGB Stars

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Abstract In this study, the age-metallicity relation for evolved stars in the solar vicinity is investigated by using spectroscopic and astrometric data of red giant branch stars (RGB). Spectroscopic data are provided from SDSS IV APOGEE DR14 catalogue and complemented with *Gaia* DR2 astrometric data. Sample stars are selected by constraining the effective temperature (T_{eff}) and surface gravity (log g) with the following constraints, $3550 \leq T_{eff}$ (K) ≤ 5600 and $0.5 \leq \log g$ (cm s^{-2}) ≤ 3.5, respectively. Furthermore, additional constraint are applied on the relative parallax errors ($\sigma_\pi/\pi \leq 0.1$) and total space velocity errors ($S_{err} \leq 9.2$ km s^{-1}), leaving 62928 stars to study. Moreover, RGB sample is constraint based on the distance to Galactic center (R_{gc}), α and Fe abundances, and distance to Galactic plane (z) of the stars in order to investigate the age-metallicity relation. Analyses show a significant change in metallicity with age for the thin and thick discs RGB stars.
Keywords: Galaxy: abundances Galaxy: evolution Galaxy: disc

INTRODUCTION

Age-metallicity relation is an important method for understanding formation and evolution of the Galaxy. Age-metallicity analyses of RGB stars in the Milky Way provide some constraints for chemical models of the Galaxy. The relation between the age and metallicity of the stars was revealed by the analyses of main-sequence stars for the first time, which was performed using the F-G spectral type stars in solar vicinity [1]. However, according to analyses of *Hipparcos* data [2] of F-G stars a relation like this cannot be encountered due to their wide distribution of age and metallicity [3]. On the other hand, in another research based on *Hipparcos* data and F-G stars analyses, gradient of the age-metallicity relationship is calculated as -0.07 dex Gyr^{-1} [4]. [5] studied age-metallicity relation by merging *Hipparcos* astrometric data with Strömgren photometry data, which were compiled by [6, 7]. They have established a prominent gradient for age-metallicity relation of early-type stars. They also have asserted that there is no age-metallicity relation for late-type stars due to their long lifetime. Another important study, based on *Hipparcos* astrometric and Strömgren photometric data, had been done by [8]. They have calculated metallicities and ages of about 14000 main-sequence stars in the solar vicinity. Nevertheless, despite of the sensitive data, researchers attributed the dispersed condition of age-metallicity relation to uncertainties of the age determinations of these stars. [9] has claimed that there can be no relation between age and metallicity for RGB stars older than 5 Gyr. [10] constituted a star sample for kinematic age determinations by selecting F-G main-sequence stars from the RAVE DR3 spectroscopic data. In their sample, by using the method of [5], they have showed that early-type stars has a distinct age-metallicity relationship, together with its disappearance by the transition from early to late-type stars. By investigating F-G type stars in solar vicinity, [11] have studied age-metallicity relation in the Galactic disc and could not find a considerable relation. On the other hand, [12], a group of researchers who analyzed the spectrum of stars in the southern sphere selected from *Gaia*-ESO programs, have determined an age-metallicity relation in solar vicinity. These researchers could not found an age-metallicity relation for stars older than 8 Gyr due to the inexplicable decrease and scatter in the metallicity of these older stars, while they obtained a flat age-metallicity relation for stars younger than 8 Gyr. According to a recent study of age-metallicity analysis of about 4000 stars depending on the trigonometric parallax data in *Gaia* DR1 TGAS catalogue [13], the gradient of age-metallicity relation of early stars older than 10 Gyr is calculated as -0.032 dex Gyr^{-1}.

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DATA

RGB stars are objects with expanding convective envelopes. In this study, 43874 stars were used as a result of the constraints on the model atmosphere parameters (T_{eff}, log g) obtained from the APOGEE DR14 catalogue [14] taking into account the locations of RGB stars in the HR diagram. Astrometric data and trigonometric parallaxes of RGB stars were obtained from *Gaia* DR2 [15]. By constraining the relative parallax errors of the stars ($\sigma_\pi/\pi \leq 0.1$), the number of stars in the sample decreased to 66240. Space velocities of the stars were calculated from the *Galpy* code by [16]. Finally, with a last constraint on total space velocity errors ($S_{err} \leq 9.8$ km s^{-1}) left 62928 stars to study.

ANALYSIS

In the classification of stars according to their population types, α-element ([α/Fe]) and iron ([Fe/H]) abundances given in APOGEE DR14 [14] were taken into consideration. Distribution of the abundances of [α/Fe] × [Fe/H] of 62928 stars that was left in the sample after the constraints is shown in Figure 1. The curve that makes the distinction of the stars with low and high α-element abundances was obtained using the Gaussian mixture model. This curve indicates the α-element abundance where the population of thick and thin discs in the Galaxy separated. The stars above the curve are rich in α-element abundance and are thick disk and halo stars. The stars below the curve is poor with α-element abundance and are thin-disc stars.

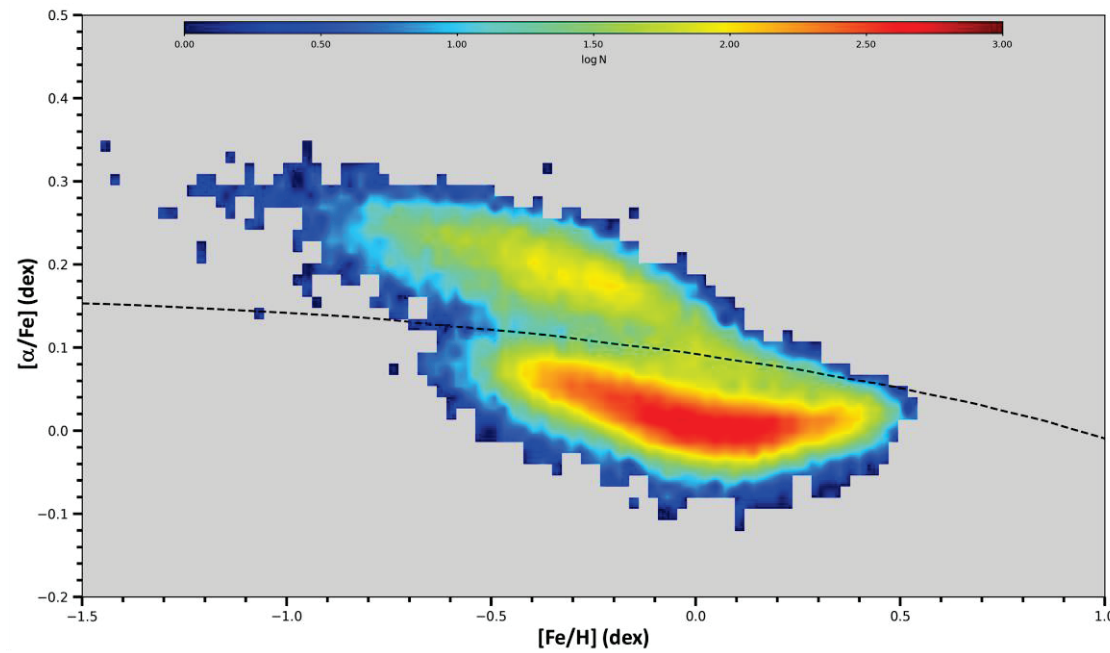

FIGURE 1. [α/Fe] × [Fe/H] distribution for the RGB stars. RGB stars in the sample are separated by population types according to the Gaussian mixture model. The red-dashed curve shows the boundary between the populations.

In order to select the sample stars in the solar vicinity, their distances from the Galactic center ($7 < R_{gc} < 9$ kpc) were considered. By separating them according to their vertical distances from the Galactic plane, distributions of age and metallicities high and low α-element abundance stars were investigated. Six and four distance intervals were used in discrimination low and high α-element abundances to z distance intervals, respectively (Figure 2). Age and metallicity diagrams were constructed by considering median values of the age and metallicity distributions. Age-metallicity gradients were estimated from linear fits to the weighted points of the age-metallicity diagrams of low and high α-element abundance stars (Figure 3). According to the analyses, age-metallicity gradients of low and high α-element abundance stars are d[Fe/H]/dt = -0.103±0.025 ve d[Fe/H]/dt = -0.182±0.032 dex Gyr^{-1}, respectively.

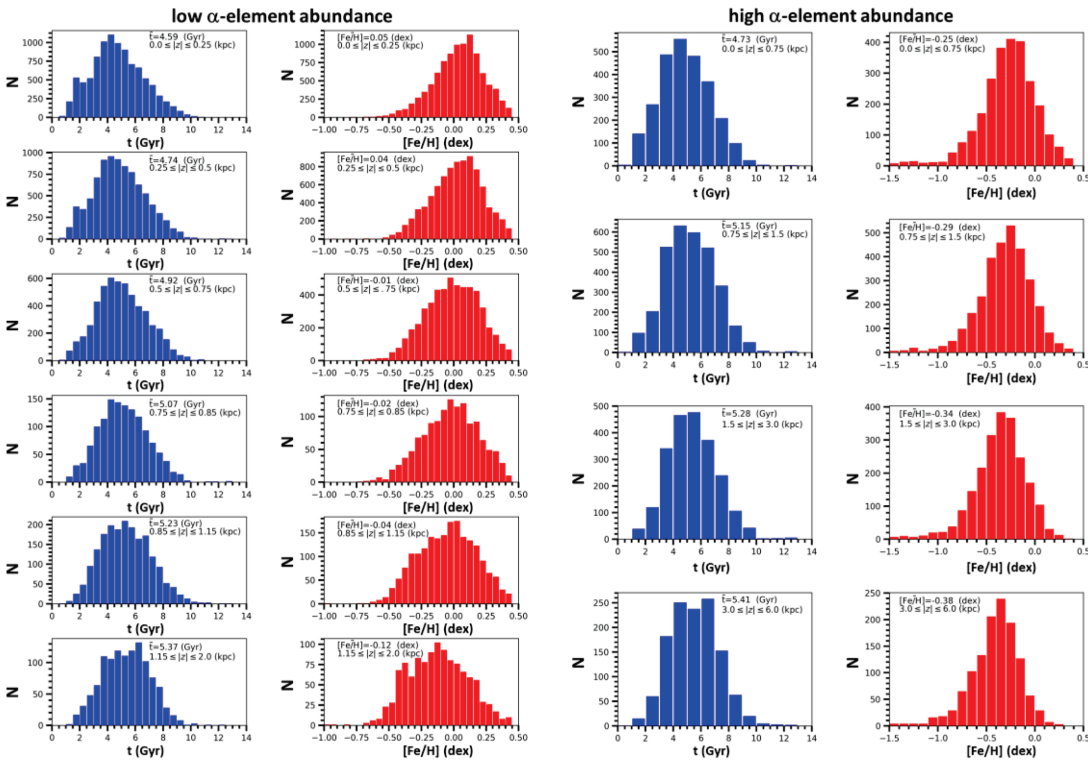

FIGURE 2. Age and metallicity histograms of selected RGB stars according to vertical distances (z) from the Galactic plane for low (left panels) and high (right panels) α-element abundances.

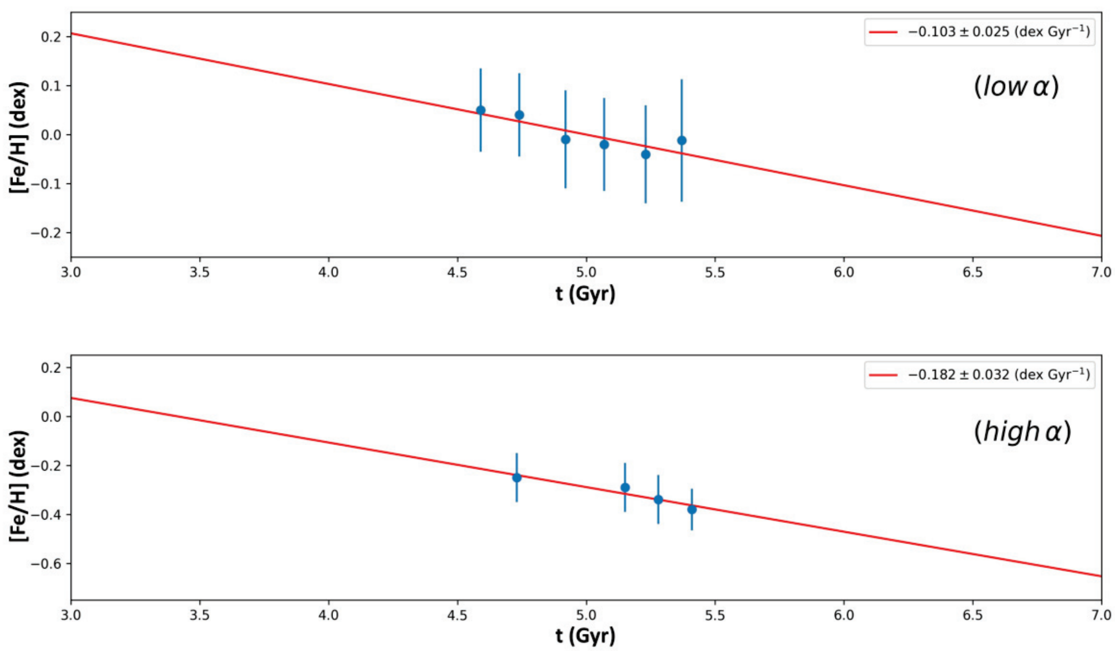

FIGURE 3. Age-metallicity relations of selected RGB stars for low and high α-element abundances.

DISCUSSION AND CONCLUSION

In this study, age-metallicity relation in the Galactic disc was investigated using spectroscopic and photometric data of RGB stars. By constraining astrometric and kinematic data, 62928 RGB stars were selected. The RGB stars in $7 < R_{gc} < 9$ kpc were selected in order to determine a reliable age-metallicity relation in the solar vicinity. RGB stars were discriminated according to population types by taking into consideration [α/Fe] × [Fe/H] diagram. These sub-samples obtained from the chemical abundances were also investigated kinematically. Median space velocity components of low and high α-element abundances are, $(U, V, W)_{\rm LSR}$ = $(-2.82, -11.88, -1.04)_{\rm LSR}$ and $(-10.18, -46.61, -0.46)_{\rm LSR}$ km s^{-1}, respectively. A comparison of V_{LSR} space velocity components of these two groups shows that metalrich thin disc has V_{LSR} = -11.88 km s^{-1} while metal-poor thick disc has V_{LSR} = -46.61 km s^{-1} [17]. It seems that population analyses of RGB sample investigated with metallicity and kinematical methods were done reliably.

By discriminating thin-disc and thick-disc/halo stars according to their z distance, age and metallicity distributions of stars in each z-distance interval were obtained. Age-metallicity relations for the low and high α-element abundance stars were investigated by calculating median age and metallicity values in each z-distance studied. Gradients for the age-metallicity relations of low and high α-element abundance stars are d[Fe/H]/dt = -0.103±0.025 and d[Fe/H]/dt = -0.182±0.032 dex Gyr^{-1}, respectively. These results indicate that there is prominent the age-metallicity relation for the stars in the solar vicinity in the Galactic disc. Age-metallicity relation that could not be found due to the migration mechanism in recent studies [e.g. 18] is clearly shown in this study.

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