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Abundance Analysis for Extremely Metal-Poor Stars from SDSS/SEGUE

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Abstract. We report the results of abundance analysis for high-resolution spectra of eight extremely metal-poor turn-off stars selected from SDSS/SEGUE. Based on differential analysis adopting stellar parameters from Balmer line profiles, we obtain the following results: i) Statistically significant scatter is found in [X/Fe] (X=Na, Mg, Cr, Ti, Sr and Ba), among which [Na/Fe] shows an apparent bimodal distribution, ii) Li abundances are $\sim$0.3 dex lower in [Fe/H]< -3.5 than the Spite plateau value without significant scatter.

Keywords. stars: abundances

1. High resolution spectroscopy of EMP stars

Turn-off (TO) stars provide an unique opportunity to study the history of the Galaxy. First of all, "intrinsic" abundances of some elements like Li, C and N are only studied with TO stars since their abundances are altered by the first dredge-up at the beginning of the red giant branch phase. In addition, differential abundance analysis in a limited range of stellar parameters enables us to achieve high precision in relative abundance even with 1D/LTE models of stellar atmosphere.

However, studies of extremely metal-poor (EMP) TO stars have been limited. Sloan Extension for Galactic Understanding and Exploration (SEGUE) in Sloan Digital Sky Survey (SDSS) is suited to pick-up candidates EMP TO stars since it is a large spectroscopic survey of stars with a medium resolution ($R \sim 1800$) and biased toward warm stars. We obtained high-resolution spectra with higher S/N ratios for the eight most metal-poor objects selected from Aoki *et al.* (2013). Results presented below are based on the analysis of these new spectra and fully discussed in Matsuno *et al.* (2017b).

Since metal absorption lines become too weak in spectra of EMP TO stars, we constrain effective temperature and surface gravity from the analysis of Balmer lines using the grid of model profiles in Barklem *et al.* (2002) as done in Matsuno *et al.* (2017a).

2. Abundance ratios

Among our eight targets, seven stars turned out to have [Fe/H]< -3.5. Abundance ratios of such low-metallicity stars are expected to reflect nucleosynthesis processes in supernova explosions of first stars.

We find statistically significant scatter in [X/Fe] for Na, Mg, Cr, Ti, Sr and Ba (Figure 1a), which could reflect supernova yields of these elements that vary depending on progenitor mass or explosion energy. However, except for Sr and Ba, the scatter is not so

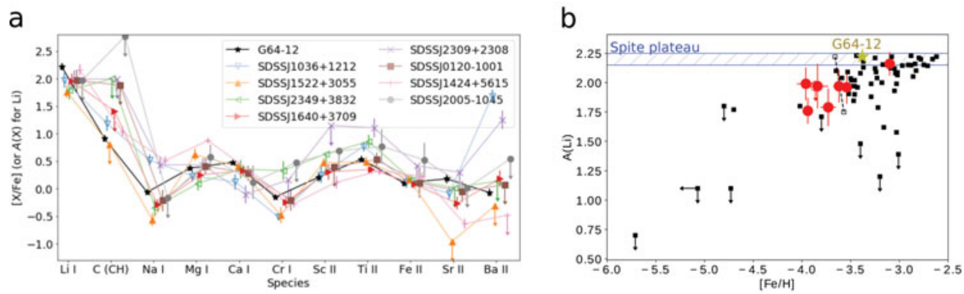

Figure 1. (a) Elemental abundances of the targets. The black thick line shows the abundance pattern of the reference star G 64–12. (b) Lithium abundances as a function of metallicity. Our targets are shown in red circles while those in literature are shown in black squares.

large as those expected from models (e.g., Kobayashi *et al.* 2006). The small scatter might indicate that even abundances of EMP stars reflect more than one supernova explosion (e.g., Jeon *et al.* 2017).

We note that [Na/Fe] shows an apparent bimodal distribution. Although similar bimodality has been reported for metal-poor stars in Norris *et al.* (2013), separations of the bimodality are different. It is desired to confirm and further investigate this bimodality with a larger sample.

3. Lithium abundances below [Fe/H]$= -3.5$

Decreasing trend in Li abundance with decreasing [Fe/H] has been previously reported. Although the cause of this trend is still unclear, it might be related to the lower Li abundance of metal-poor stars than the prediction from standard big bang nucleosynthesis models. We extend the study to lower metallicity to understand the nature of this trend.

All stars below [Fe/H]$= -3.5$ show low Li abundances with insignificant scatter (Figure 1b). By combining our results with a literature sample, A(Li) seems to be almost constant between $-4.5 <$[Fe/H]< -3.5. This result provides a new constraint on models proposed to explain the lower Li abundances than that predicted by the Big Bang nucleosynthesis.

In the near future, the sample of EMP TO stars will increase thanks to ongoing large spectroscopic surveys such as LAMOST. In addition, we will be able to investigate the impact of stellar evolution on abundance ratios with a help of evolutionary status constrained by parallaxes in the next data release of *Gaia*.

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