Rediscovering our Galaxy
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Lifting the Veil on Ultra Metal-Poor Stars in the Outermost Halo

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Abstract. The study of extremely metal-poor (EMP; [Fe/H] < -3.0) and ultra metal-poor (UMP; [Fe/H] < -4.0) stars is crucial for better understanding first-star nucleosynthesis and constraining the initial mass function in the early Universe. However, UMP stars discovered in the past 25 years only number ∼25. A few recent theoretical studies have pointed out that there is likely to exist large numbers of EMP and UMP stars in the periphery of the Galactic halo, at distances exceeding 30-50 kpc. We present identifications of several new EMP/UMP stars and introduce a survey to expedite discovering hundreds to thousands of EMP/UMP stars in the outermost halo (as well as in the local volume) over the next few years, which could revolutionize chemical-evolution studies of the Galaxy.

Keywords. General: nucleosynthesis, Method: data analysis, Galaxy: halo, stars: abundances

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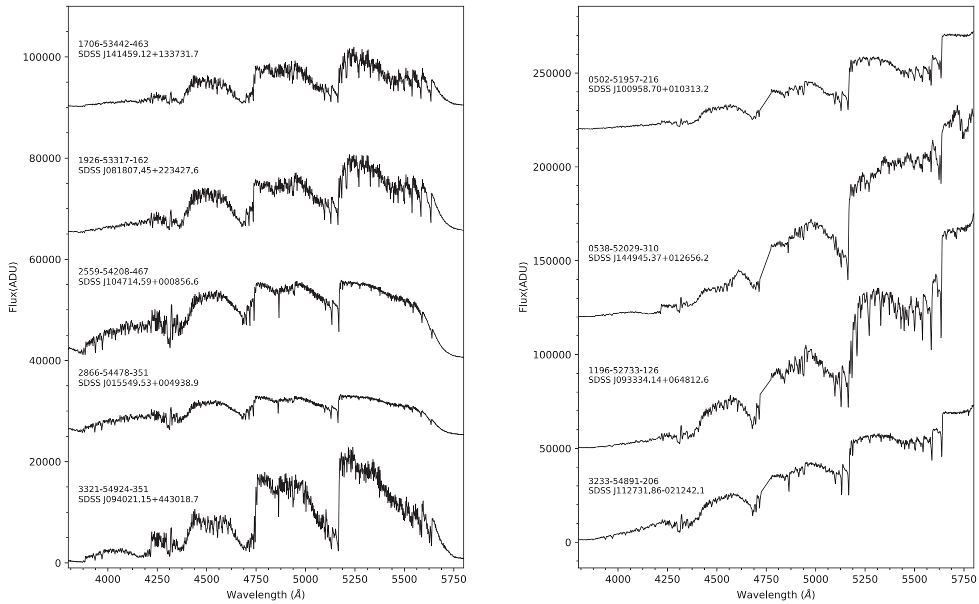
More than 80% of UMP stars (Placco *et al.* 2014) are Carbon-Enhanced Metal-Poor (CEMP) stars without strong enhancement of heavy elements such as Ba and Eu (CEMP-no, Beers & Christlieb 2005). To identify UMP candidates, we first visually inspected the SDSS spectra of CEMP stars with estimated [Fe/H] < -3.5 based on the SSPP pipeline by Lee *et al.* (2008). Then we re-binned the spectra of the faintest (and likely most distant) stars with very low-quality ($5 <$ S/N < 10), in order to increase their S/N, and reran the spectra through the n-SSPP pipeline (Beers *et al.* 2014), a special version of the SSPP pipeline modified to run on non-SDSS spectra. Finally we selected a few hundred final EMP/UMP candidates based on the above procedures.

We recently began a pilot survey of 9 brighter candidates to obtain higher-quality medium-resolution spectroscopy with the LBT/MODS and Gemini-S/GMOS. The reduced spectra are shown in Figure 1. Based on both the visual inspection of Ca II K, H lines at 3933 Å and 3968 Å and our preliminary results shown in Table 1, we have confidently identified true EMP/UMP stars on our first try. Three of them are likely CEMP giants; the rest are likely dwarfs, based on their kinematics. The brightness selection preferentially identified more dwarf carbon stars. These dwarf carbon stars are very interesting objects, since they are similar to the canonical UMP dwarf carbon star G77-61 (Plez & Cohen 2005), which is a Group III CEMP-no star ([Fe/H] $= -4.0$; A(C) ∼7.0, Yoon *et al.* 2016). The early success of this survey provides confidence that our approach will expedite the identification of numerous additional EMP/UMP stars.

Large samples of EMP/UMP CEMP giants and dwarfs with available *Gaia* kinematics will provide a great opportunity to understand first-star nucleosythesis, Galactic chemical evolution, and the chemodynamical assembly history of the Galaxy.



(a) LBT MODS spectra (b) Gemini GMOS spectra

Figure 1. The left and right panels show the $R \sim 2000$ optical spectra of the UMP candidates observed with the LBT/MODS and the Gemini-S/GMOS, respectively.

Table 1. Stellar Parameter Estimates for Follow-up Spectra of UMP Candidates

SDSS PID-MJD-FIBER	T_{eff} (K)	log g (cm/s^2)	[Fe/H]	[C/Fe]	A(C)[1]	Subclass[2]
0502-51957-216	4870	4.8	−4.0	+2.8	7.2	Group III
0538-52029-310	4086	0.0	−4.0	+2.8	7.2 (7.6)	Group III
1196-52733-126	4450	5.0	−3.8	+2.7	7.3	Group III
1706-53442-463	3872	4.0	−4.5	+2.8	6.2	Group II/III
1926-53317-162	4400	5.1	−5.0	+4.1	7.6	Group III
2559-54208-467	4836	1.4	−3.8	+3.4	8.0 (8.2)	Group I/III
2866-54478-351	4984	5.0	−4.0	+3.4	7.8	Group I/III
3233-54891-206	4880	5.0	−3.6	+2.5	7.3	Group I/III
3321-54924-351	4128	0.1	−3.8	+2.6	7.2 (7.5)	Group III

Notes:
[1] A(C) = [C/H] + 8.43. The parenthesis value indicates the corrected carbon value based on stellar evolution using the method of Placco *et al.* (2014).
[2] Based on the A(C)-[Fe/H] diagram of Yoon *et al.* (2016) to separate CEMP classes.

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