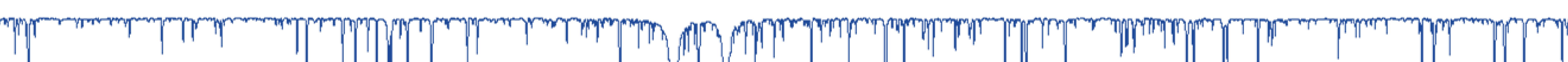

Signatures of Peculiar Supernova Nucleosynthesis in Extremely α-enhanced Stars

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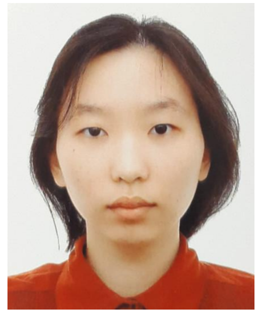


Image: Solar fluxatlas2005 by R. L. Kurucz

Abstract

We have performed a spectroscopic study on several extremely alpha-enhanced stars having [Fe/H] ~ -1. The data were obtained with the GRACES (R ~ 40000) of the GEMINI 8m telescope. We find that O, Mg, Ca, Ti, V abundances are anomalously high in some of our sample, compared to core-collapse model predictions and those of other field stars of similar metallicity. For example, our program stars have strong enhancement of titanium ([Ti/Fe] = 0.9), calcium (0.69) and vanadium (0.9), compared to [X/Fe] ~ 0.3 for most stars with similar iron abundances. Plus, some stars have strong oxygen enhancement ([O/Fe] > 0.7), which is not usual for [Fe] ~ -1 stars. We compared our results to the observed abundance patterns of VMP stars ([Fe] < -2, Cayrel et al., 2004). Overabundances of alpha-elements except for silicon compared to the case of the Cayrel sample are clearly shown. We discuss implications of our finding for nucleosynthesis.

I. Introduction

Galactic metal-poor stars with [Fe/H] < -1

- Old stars that were formed 10 Gyrs ago
- Mostly enriched by core-collase SNe (CCSNe) of massive stars.

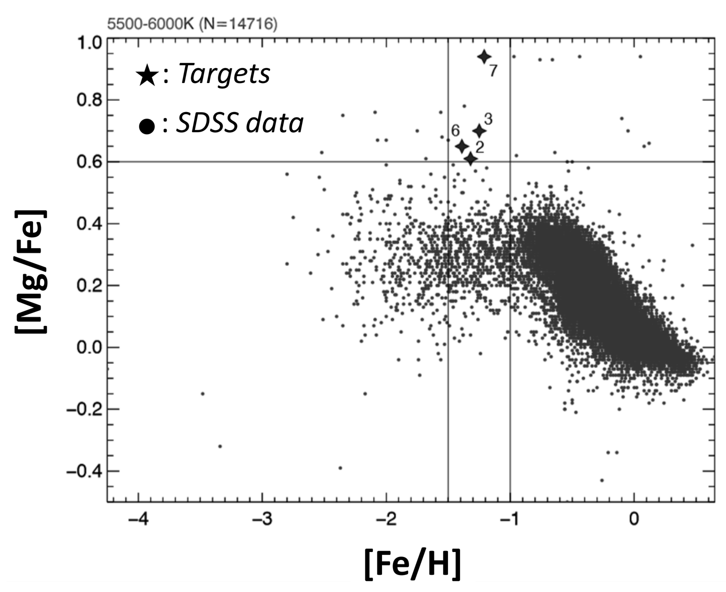
α-elements and chemical evolution of the Galaxy

- Forms plateau at [Fe] < -1 due to CCSN enrichment in the early universe, and gradually decreases by iron contribution of Type Ia supernova. (Timmes+, 1995)
- Strong α-enhancement above plateau may imply exotic environment of early nucleosynthesis of α- elements (e.g. PISN, Fall-back SN; Nomoto+, 2013)

II. Observation

Target selection

- To find such signature of the early universe, we choose stars with high Mg to Fe ratio from the SEGUE database. (abundance & stellar parameters derived by Lee+, 2008) **+** FGK type, main-sequence (log g > 4), g < 16



- ✓ **-1.5 < [Fe/H] < -1**
- ✓ **[Mg/Fe] > 0.6**
- ✓ 4500K < T < 6000K
- ✓ log g > 4
- ✓ g < 16

Observation

- *Gemini* North 8.2m telescope + *CHFT ESPaDOnS* Echelle Spectrograph *(GRACES)*
- Wavelength coverage: 4,000-10,000A
- Resolution: 40,000 (star+sky mode)
- S/N ratio: 50 (4500A) to 100 (10000A)

Data reduction

- DRAGRACES + some IDL Procedures written by authors

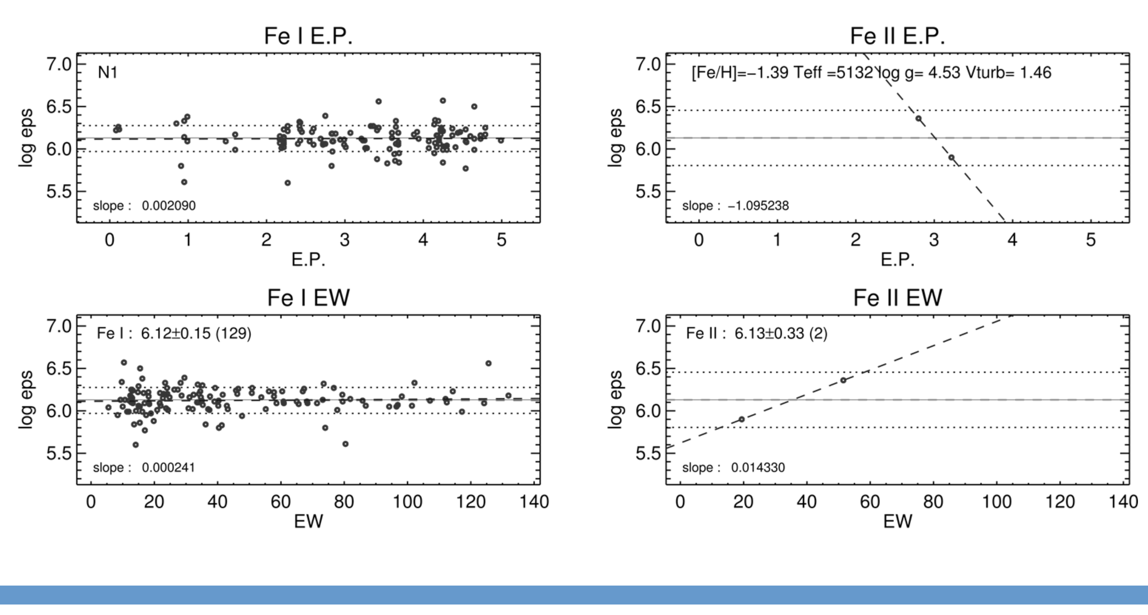
III. Abundance Analysis

Equivalent width estimation

- Using IDL-based code *TAME* (Kang & Lee, 2012)

Abundance analysis

- *Kurucz* (α-enhanced) atmosphere model (Castelli & Kurucz, 2004) + MOOG (Sneden, 1973)
- Parameter estimation using Fe I & II lines (e.g. N1)



IV. Results & Discussion

Summary of stellar parameters & element abundance ratios [X/Fe] of program stars

- *Total # of lines for each star ~ 200*

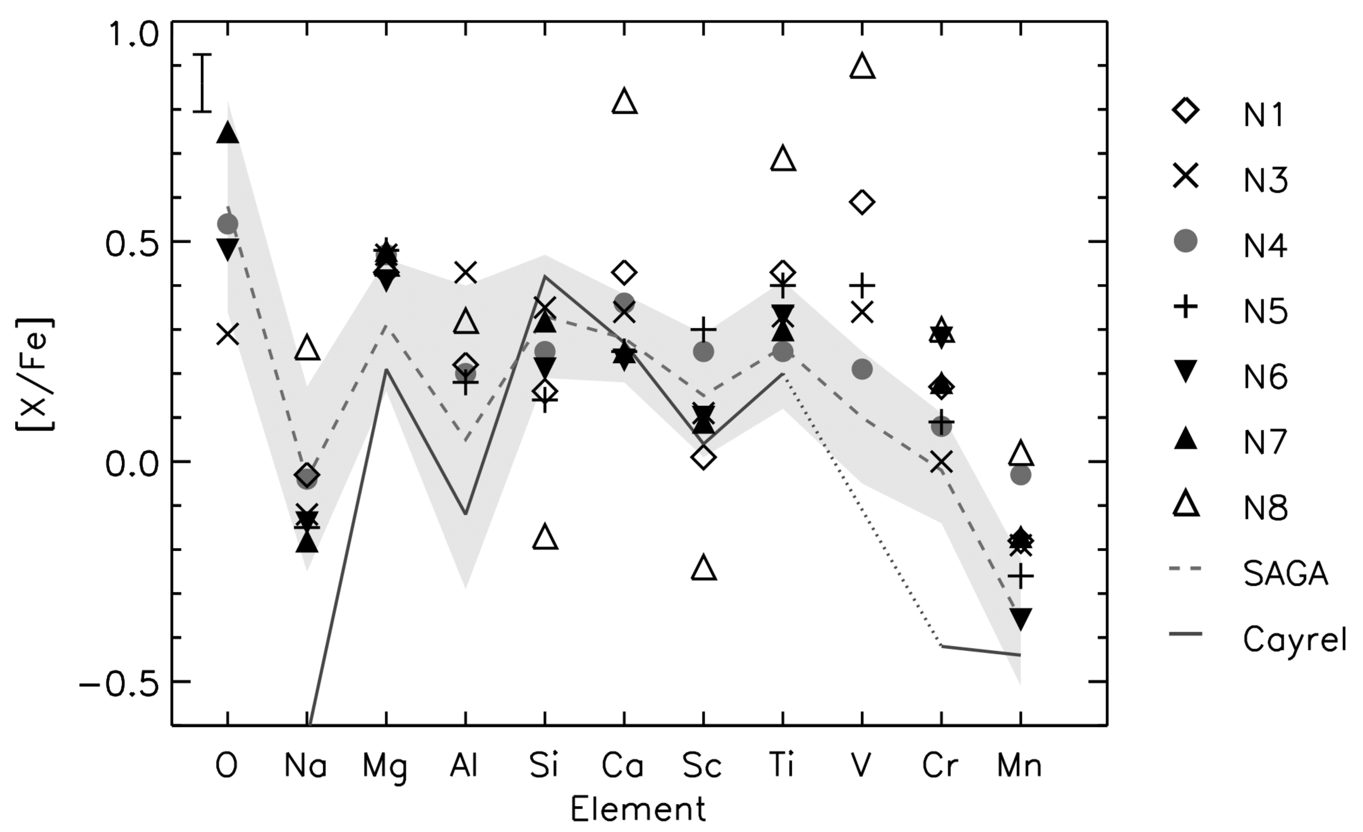
† T_eff : effective temperature [K], V_t : turbulent velocity [km/s], V_r : radial velocity [km/s]

	[Fe/H]	T_eff	Log g	V_t	V_r	O	Na	Mg	Al	Si	Ca	Sc	Ti	V	Cr	Mn
N1	-1.38	5130	4.5	1.5	+50.6	-	-0.03	0.43	0.22	0.16	0.43	0.01	0.43	0.59	0.17	-0.18
N3	-1.30	5450	4.4	1.5	-36.0	0.29	-0.12	0.47	0.43	0.35	0.34	0.11	0.33	0.34	0.00	-0.19
N4	-1.00	5120	3.0	1.1	-68.6	0.54	-0.04	0.47	0.20	0.25	0.36	0.25	0.25	0.21	0.08	-0.03
N5	-1.36	5000	4.8	0.7	-166	-	-0.15	0.48	0.18	0.14	0.25	0.30	0.40	0.40	0.09	-0.26
N6	-1.39	5930	4.3	1.1	-371	0.48	-0.14	0.41	-	0.21	0.23	0.10	0.33	-	0.28	-0.36
N7	-1.34	5480	4.5	0.9	-105	***0.75***	-0.18	0.48	-	0.32	0.25	0.09	0.30	-	0.18	-0.17
N8	-1.38	5070	3.8	2.2	-336	-	0.26	0.45	0.32	-0.17	***0.82***	-0.24	***0.69***	***0.90***	0.30	***0.02***
VMP stars (Cayrel+, 2004)						-	-0.63	0.21	-0.12	0.42	0.27	0.04	0.20	-	-0.42	-0.44

‡ Typical error of e[Fe/H] ~ 0.01, e(T_eff) ~ 20, e(Log g) ~ 0.1 and e(V_t) ~ 0.05

- ✓ N7 shows high oxygen abundance [O/Fe] > 0.7
- ✓ For the case of α-elements, [Mg/Fe] and [Ca/Fe] are large while [Si/Fe] is relatively small.
- ✓ N8 has very high [Ca/Fe], [Ti/Fe] and [V/Fe] ratio along with relatively strong [Mn/Fe], which makes the star different from normal galactic stars. This implies some peculiar types of SN contribution.

Comparison of our stars and SAGA database



- ✓ ***N1 & N8 : Overabundance of Ca, Ti and V & deficient of Si are clearly shown.***

i) Dashed line: abundance avg. of galactic stars with ***-1.5 < [Fe] < -1*** from SAGA database (The shaded area represents the standard deviation.)

ii) Error bar (upper left): typical error of abundance ratios

Element abundance of N8 and Implication on SN nucleosynthesis

- High [Mg/Fe], [Ca/Fe], [Ti/Fe], [V/Fe], [Mn/Fe], and relatively low [Si/Fe]
- ➢ **It may indicate the influence of helium detonation in accreting white dwarfs (Waldman et al. 2011) or Ca-rich CCSN (e.g., Gvaramadze+2017)**

V. Summary & Conclusion

Summary of results

- We took spectroscopic observation of 7 magnesium-enhanced galactic MP stars selected from SEGUE database. We find some of our stars show strong Ca and Ti enhancement compared to Si.
- We find that some of our sample have overabundances of Mn and V compared to other galactic stars. This abundance pattern cannot be explained by chemical evolution model from CCSN and Type-Ia SN nucleosynthesis.
- Helium detonation or Ca-rich CCSN model could be a possible explanation of our result.

Possibility of overestimation

- Abundance values of saturated lines are sensitive to turbulent velocity. A low S/N ratio of spectra may cause selection bias toward strong lines. This can cause an overestimate of turbulent velocity and line abundance.

References

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