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Origin of the most iron-poor stars in the Galaxy

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Big Bang Cosmology



History of Search for Pop. III [Fe/H] [Fe/H]=log(X_{Fe}/X_H)-log(X_{Fe}/X_H). ▲1948:Gamov Big Bang primordial nucleosynthesis ex) [Fe/H]=0 : solar 0 HD140283: =-∞: Pop.III Bond survey [Ca/H]=-1.9 [Fe/H]~-2.6 -1 HK survey [Fe/H]=-1.2 (-2.5) Bond(1970,1980) (1985:1992) HE survey SEGUE, Chamberlian & Aller (1951) -2 (1990:2001) Skymapper no stars below [Fe/H]<-3 (~2010-) Bond (1981) -3 HE0557-4840 G64-12 **SDSS** [Fe/H]=-4.75 [Fe/H]=-3.5(-3.28) J102915+172927 Carney & Peterson (1981) Norris et al. (2007) -4 [Fe/H]=-4.99 Caffau et al. (2011) HE0107-5240 CD-38°245 [Fe/H]=-5.3 -5 [Fe/H]=-4.5(-4.01) Christlieb et al. (2002) Bessel & Norris (1984) SMSS J0313-6708 -6 G77-61 HE1327-2326 [Fe/H]<-7 [Fe/H]=-5.6 (-4.03) Initial measurement [Fe/H]=-5.6 Keller et al. (2014) Gass et al. (1987) -7 corrected value Frebel et al. (2005) 2020 2010 1970 1950 1960 1980 1990 2000

Hyper Metal-Poor Stars

- Most of HMP stars are carbon-enhanced stars!
 - Carbon-Enhanced Metal-Poor (CEMP) stars are very common among metal-poor stars.
 mass transfer from AGB stars



SAGA viewer

Proposed Scenarios for the Origins of CEMP Stars

- Origin of EMP stars
 - Star formation from the gas influenced by SNe in the very early universe.
- Origin of CEMP stars
 - Mass transfer from AGB stars in binary systems (TS+04)
 - CEMP-s stars are thought to belong to binary systems (Lucatello+05), but not for CEMP-no.
 - Star formation from gas affected by peculiar supernovae in the earliest generation of massive stars (Umeda+03, Limongi+04)
 - Abundance patterns are well reproduced by mixing and fallback models.
 - Star formation affected by massive fast-rotating stars (Meynet +06)
 - Abundance patterns are well reproduced by rotational mixing.





^{(¥) 8.4} 8.2 8.2 8.1 8.0 4.5 cm/b)d bol 3.5 3 2.5 10⁻¹ 16O φO 10-2 ²⁰Ne 10-3 ²¹Ne $\times 10^{-4}$ 22Ne 10-5 10-6 ²⁵Mg 10-7 10-8 13C 10-9 1e+07 1e+08 1e+09 1e+10 TS+04 t (sec)

Umeda+Nomoto03

Nucleosynthesis models

- One zone approximation during the He shell flashes (Fujimoto+99, Aikawa+01)
- p-, α-, β-, n-reactions up to Bi are included in nuclear network (Aikawa+01, Nishimura+08, Yamada+, in prep.).



n-capture nucleosynthesis in HMP stars

Nucleosynthesis of H-mixing into He-flash convective zones (He-FDDM) depends on:

- Minit, Mc: stellar total/core mass
- T_{max} : strength of shell flashes
- [Fe/H]_{He}: iron supply from the envelope to Heflash convective zones
- Δ(¹³C/¹²C): amount of H-mixing
- ∆t: duration of H-mixing
- [C/H]_{surf}: dredge-up efficiency





Key ingredients: Origin of CEMP stars

- Observed characteristics of CEMP:
 - CEMP-s disappears at [Fe/H] < -3.
 - CEMP-no peaks at [Fe/H] = -3.5.
 - CEMP-s + CEMP-no is more or less continuous.

should be understood as the [Fe/H] dependence of the s-process



Possible solution by binary scenario:

- \cdot M < 3.5 M for CEMP-s.
- \cdot 3.5 < M / M < 6-8 M for CEMP-no.
- Inefficient NEMP production by suppressing the hot bottom burning or mass loss. (Wood11, TS+13)



Fraction of C-rich stars

Comparison of models and observations using binary population models



Summary

- Origins of the most iron-poor stars have been explored based on the scenario of binary mass transfer and nucleosynthesis.
- We propose that the abundance patterns of three most ironpoor stars are results of nucleosynthesis in AGB stars
- To identify the origin of the most iron-poor stars, we should care about the origin of CEMP stars:
 - Why CEMP-no fraction increases / CEMP-s fraction decreases with decreasing [Fe/H]?
 - Why total CEMP fraction (CEMP-s+CEMP-no) is continuous?
 - Why the most iron-poor stars are so rare?
- This scenario suggests that the IMF of the first stars are dominated by massive stars with the non-negligible contribution of low-mass stars.