Chemical composition of HE1327-2326, the most iron-deficient star known

最も鉄組成の低い星 HE1327-2326 の発見と化学組成解析

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Background: metallicity (Fe abundance) distribution of halo stars

Until 2001, no halo star having $[\text{Fe/H}]<-4$ was known, nevertheless large efforts to search for metal-deficient stars.

Chriestlieb et al. (2002, Nature 419, 904) reported a star with $[\text{Fe/H}]=-5.3$ (HE0107-5240). This is a giant with a large excess of carbon ($[\text{C/Fe}]\sim+4$).

Many models have been proposed to interpret the low iron abundance and the excess of carbon in HE0107-5240. Further search for stars with $[\text{Fe/H}]<-4$ has been strongly desired.
A Subaru/HDS program: Chemical abundance patterns of the first generations of stars

Sample selection:
1) Objective prism surveys:
   - HK-survey (Beers et al. 1985, 1992)
   - Hamburg/ESO survey (Christlieb et al. 2003)

2) Medium resolution spectroscopy
   ESO 1.5m, 3.6m; SSO 2.3m, KPNO 2.3m; etc.

3) HERES (Barklem et al., 2005)
A Subaru/HDS program:
Chemical abundance patterns of the first generations of stars

High resolution spectroscopy:
- R=60,000 for 4000--6800A
- S/N~100--200@4500A

2003 Dec. 2 nights (1 clear night)
2004 May/June 4 nights (3.5 clear nights)
2005 Feb/March 3.5 nights (3 clear nights)
2005 June 5 nights (scheduled)

Photometry
determination of atmospheric parameters
ESO/Danish 1.5m; KPNO 0.9m; CTIO 0.9m; MAGNUM
HE1327-2326: the most iron-deficient star known
Evolutionary status of HE1327-2326: very close to main-sequence = an unevolved star

dots: stars in the globular cluster M15

HE0107-5240

HE1327-2326
1. Iron abundance

Medium resolution spectra →

High resolution spectra →

very weak Fe lines → [Fe/H] = -5.4

detection of CH molecular bands → excess of carbon
2. A large excess of carbon

HE1327 and HE0107 have very high C/Fe ([C/Fe]~+4) → A common origin of the peculiar abundance pattern
3. Abundances of N, Na, Mg and Al

HE1327 show excesses of these elements with respect to HE0107

\([\text{Mg/Fe}]\) of HE1327 is \(~1.5\) dex higher than that of HE0107
Comparison of the abundance patterns between HE1327 and HE0107

Average of extremely metal-poor stars
4. The light Neutron-capture element Sr

The two Sr resonance lines are detected only in HE1327-2326, while no Ba line is seen.
→excess of light neutron-capture elements
4. The light Neutron-capture element Sr

![Graph showing data points for the light Neutron-capture element Sr.](image)

- **HE1327-2326**
- **HE0107-5240**

**Legend:**
- ★ This work
- ○ Francois et al. 2003
- □ Cohen et al. 2004
- • Carretta et al. 2002
- ♦ Honda et al. 2004
- ● Aoki et al. 2005
- ▲ Aoki et al. 2004
5. Upper-limit of Lithium Abundance

- $T = 6380K, [\text{Fe/H}] = -3.2$
- $T = 6200K, [\text{Fe/H}] = -3.5$
- $T = 6200K, [\text{Fe/H}] = -3.2$
- $T = 6180K, [\text{Fe/H}] = -5.5$
5. Upper-limit of Lithium abundance

\[ T_{\text{eff}} > 6000 \]

HE1327–2326

This work

\[ \circ \] Ryan et al. 1999

\[ \star \] Norris et al. 2000
Summary: the chemical abundance pattern of the unevolved star HE1327-2326

1. The iron abundance ([Fe/H]=-5.4) is lowest in halo stars known to date. No star has been found in -5<[Fe/H]<-4.

2. The excess of carbon is significant ([C/Fe]=+4), as found in HE0107-5240. These two stars have similar enrichment history.

3. The excesses of N, Na, Mg and Al is significant in HE1327-2326.

4. The excess of Sr is found in HE1327-2326.

5. The Li abundance of HE1327-2326 is significantly lower than the values found in halo unevolved stars.
Possible interpretations

• Population III (=1\textsuperscript{st} generation star) scenario: HE1327 (as well as HE0107) formed from primordial (metal-free) clouds, but polluted by interstellar medium (Fe etc.) and AGB stars (C etc.).
  cf. Suda et al. 2004

• Population II (>2\textsuperscript{nd} generation star) scenario: HE1327 (as well as HE0107) formed from clouds polluted by 1\textsuperscript{st} generation massive stars, that have provided C-rich material.
  -“Faint supernova”: Umeda & Nomoto 2003,
    Iwamoto et al. 2005
  -Rotating massive star: Meynet et al. 2006
Comparison with the calculation of “faint supernova” model

Iwamoto et al. 2005
Ongoing & future work

Further observing for HE1327-2326 ... was made with VLT. → detection of OH molecular lines.

Frebel et al. 2006 (submitted to ApJL)

Further survey & spectroscopy:
- Hamburg/ESO survey + VLT
- SDSS-SEGUE + Subaru