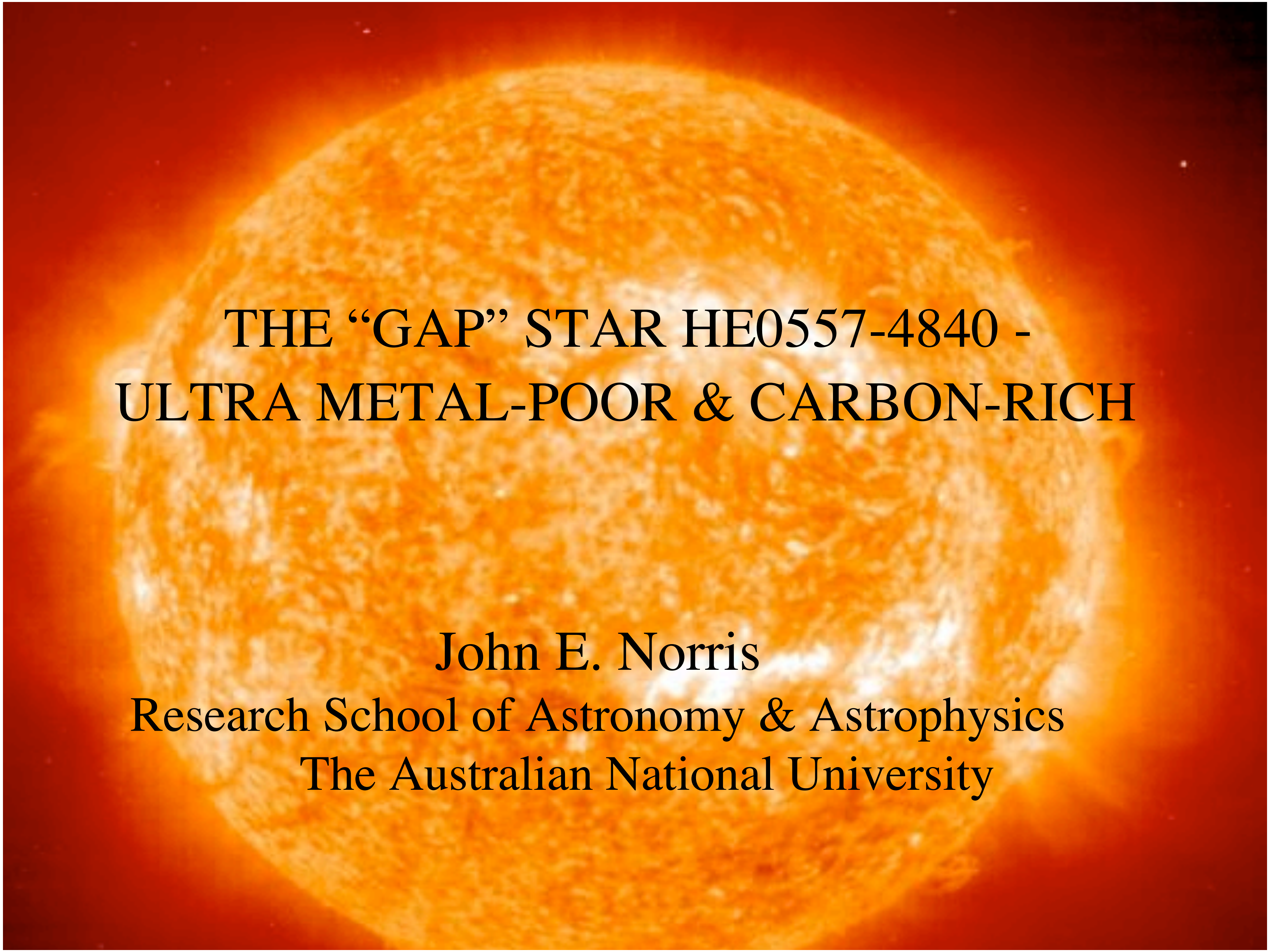

THE “GAP” STAR HE0557-4840 - ULTRA METAL-POOR & CARBON-RICH

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Collaborators:

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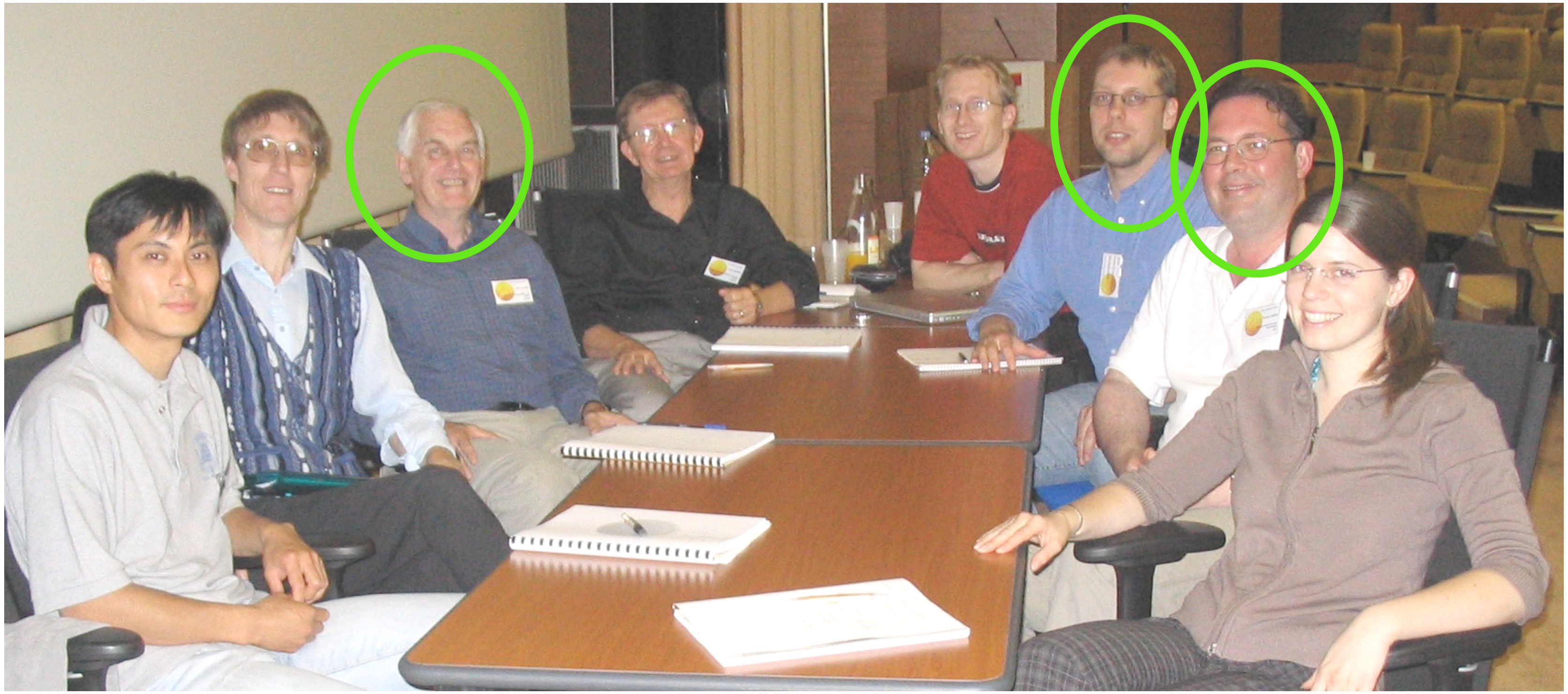


Andreas Korn

Kjell Eriksson

Lutz Wisotzki

Dieter Reimers

Plan of attack

Introduction: why study stars with [Fe/H] < -3.0

- Stars closest to Big Bang
- Probe conditions at Z > 4-5 when first heavy element producing objects formed
- Insight into Initial Mass Function at earliest times
- Constrain explosions of first supernovae
- Information on manner in which SNe ejecta were incorporated into later generations
- Constrain manner in which the Galaxy formed

HE0557-4840: discovery, observations, analysis and abundances

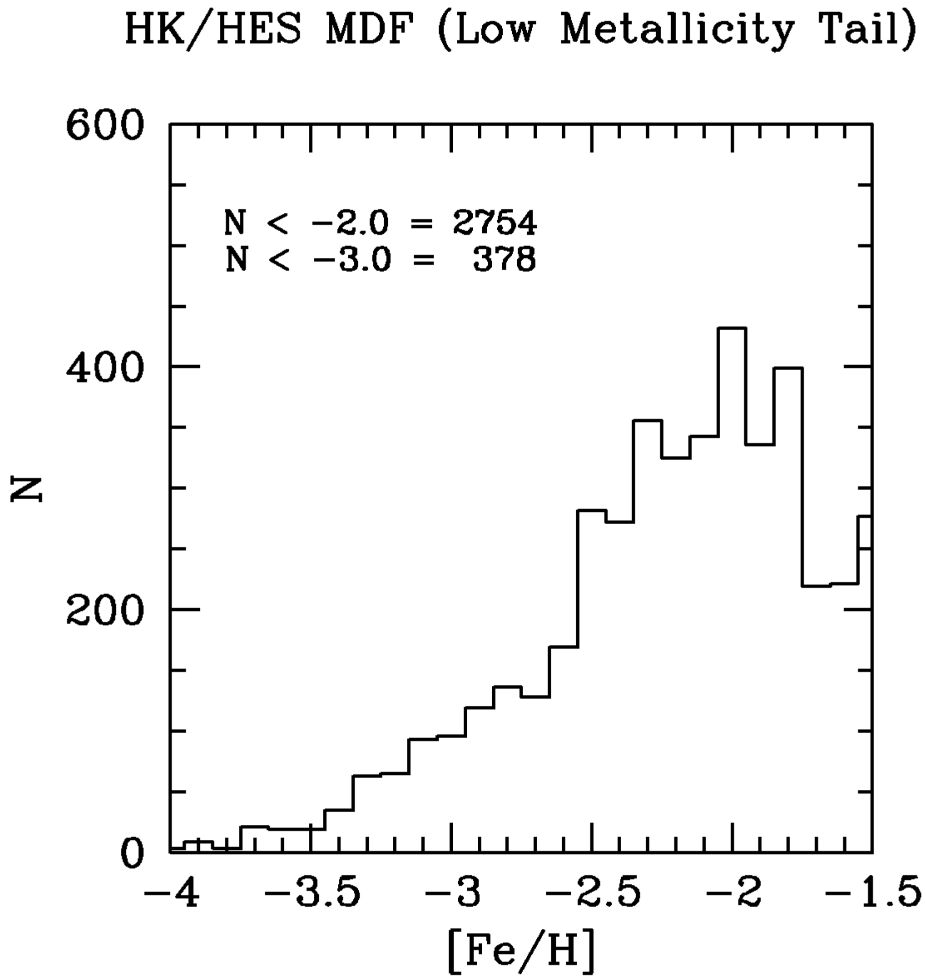
Implications

Halo Metallicity Distribution Function

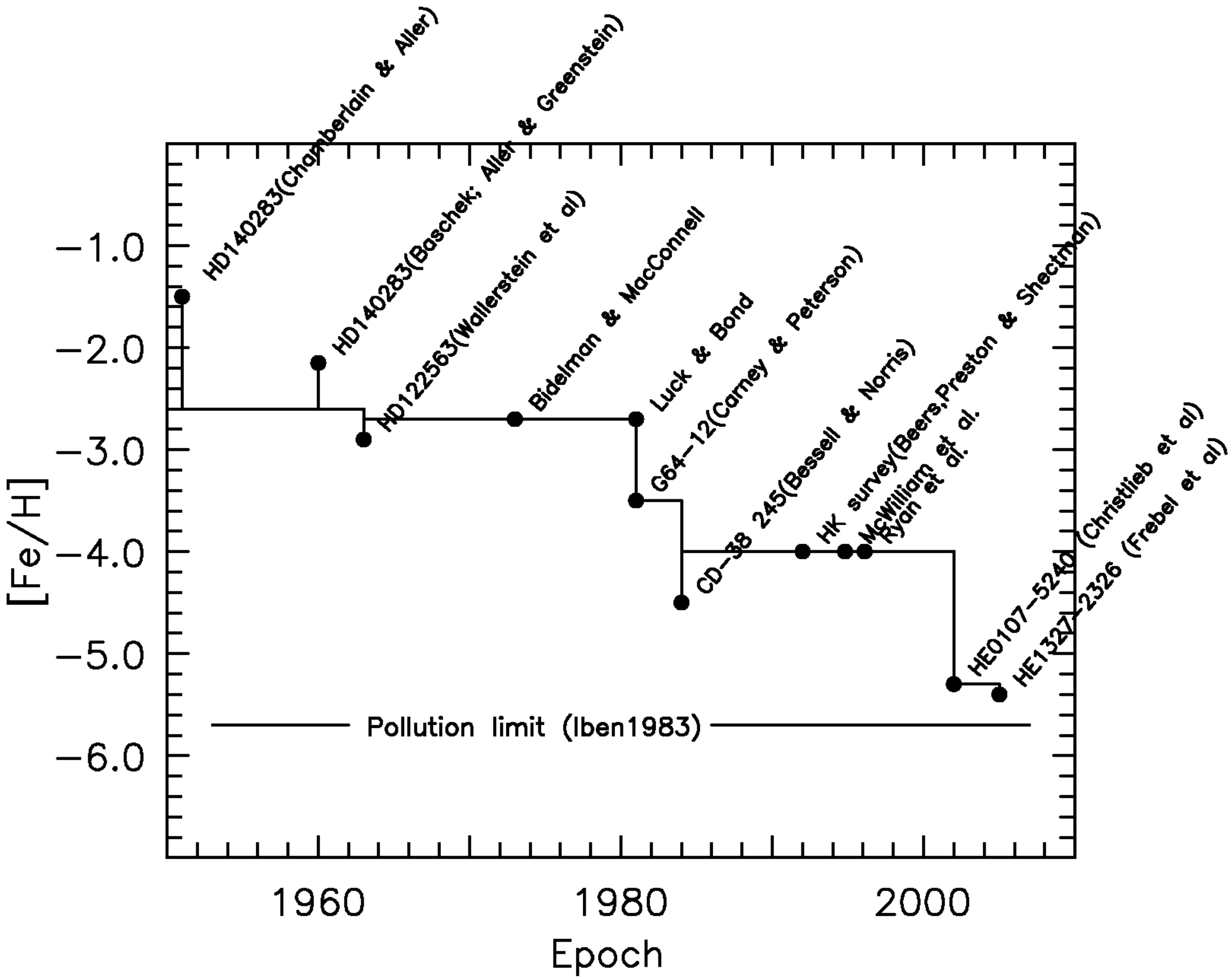
Beers et al. 2005
IAU Symposium 228

Plus
HE0107-5240, [Fe/H] = -5.3
HE1327-2326, [Fe/H] = -5.4

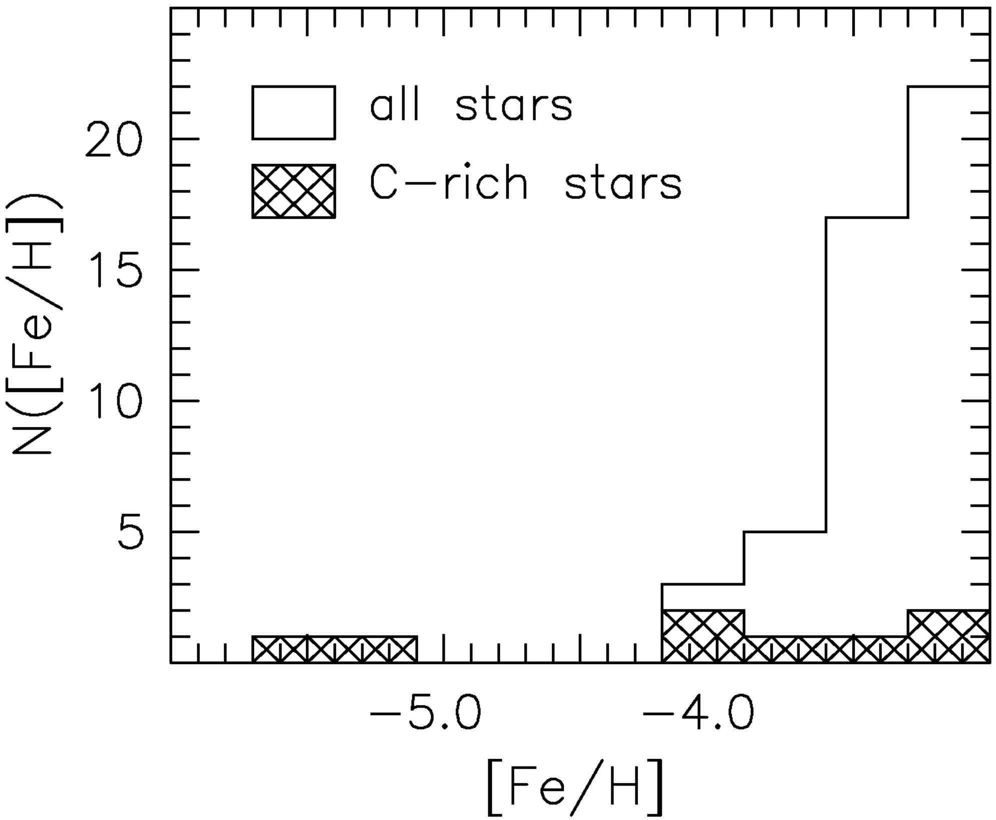
The Big Bang



The Most Metal-Poor Star as a Function of Time

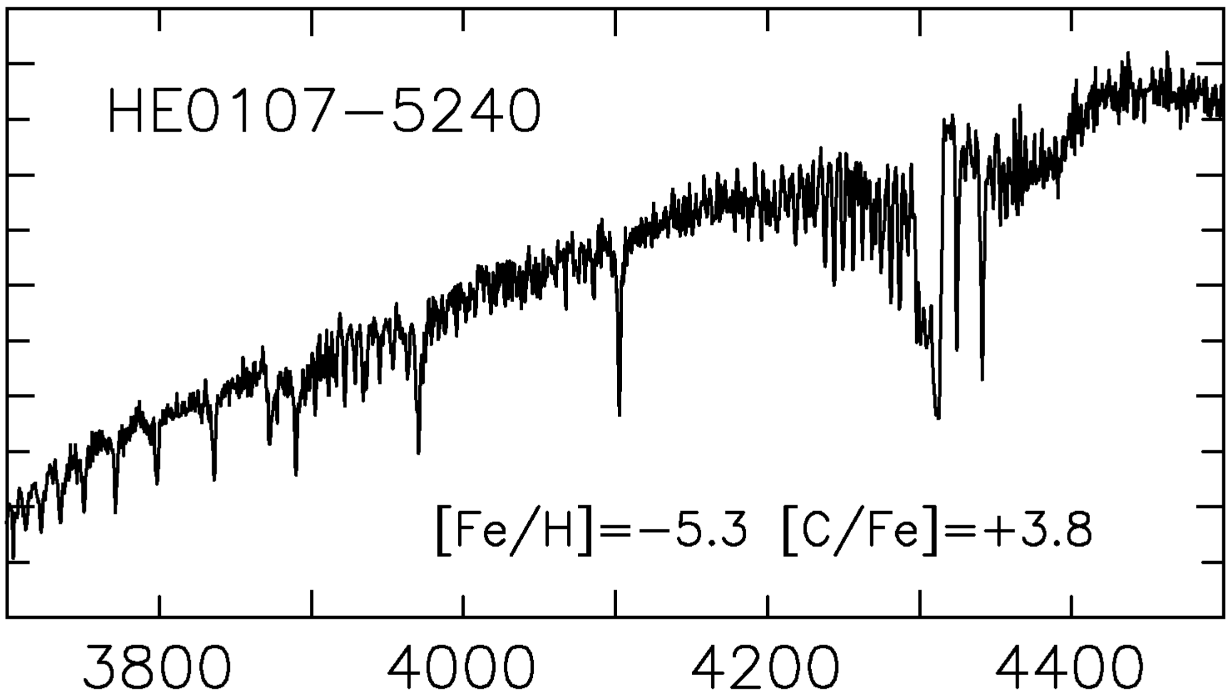


MDF of 50 stars with high-resolution abundance analysis and [Fe/H] < -3.0

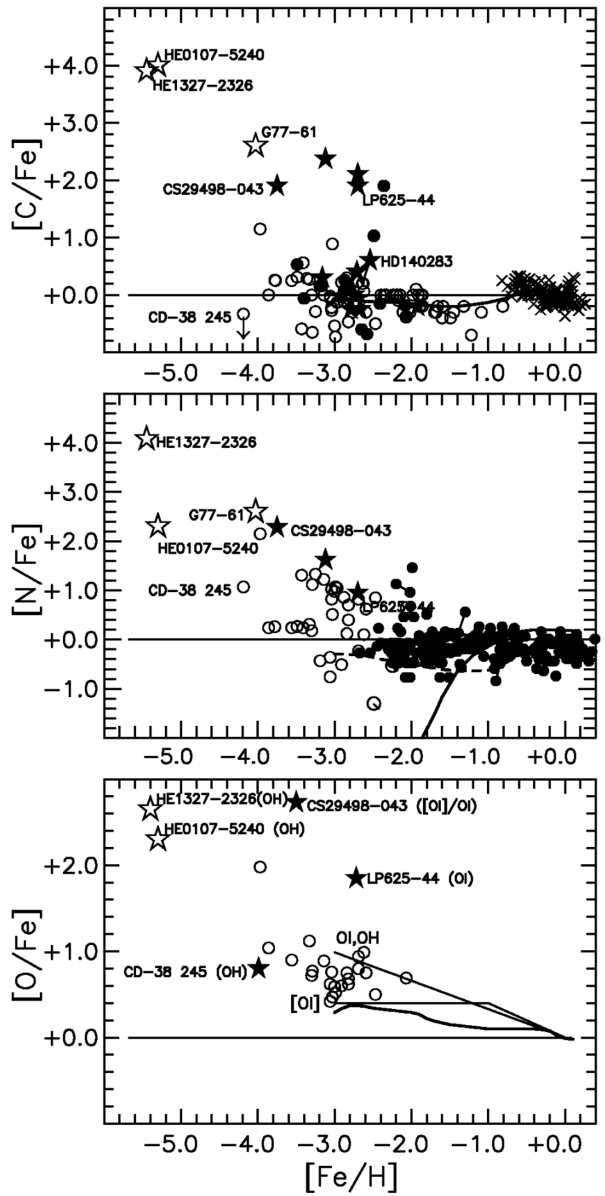


Norris et al. 2007, ApJ, in press

The most metal-poor giant - very C-rich

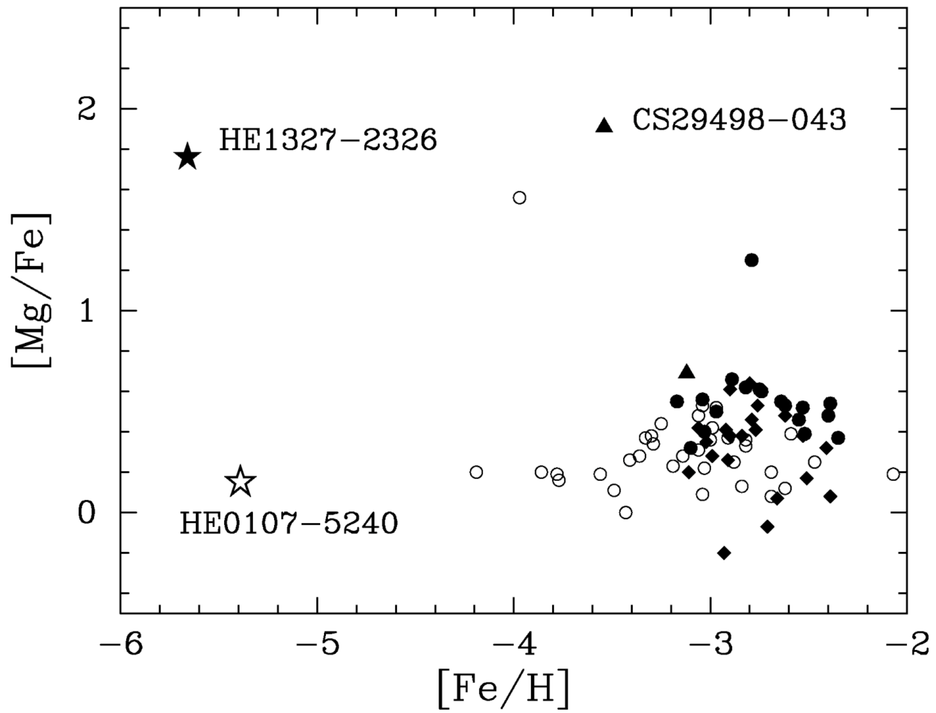


CNO vs. [Fe/H]



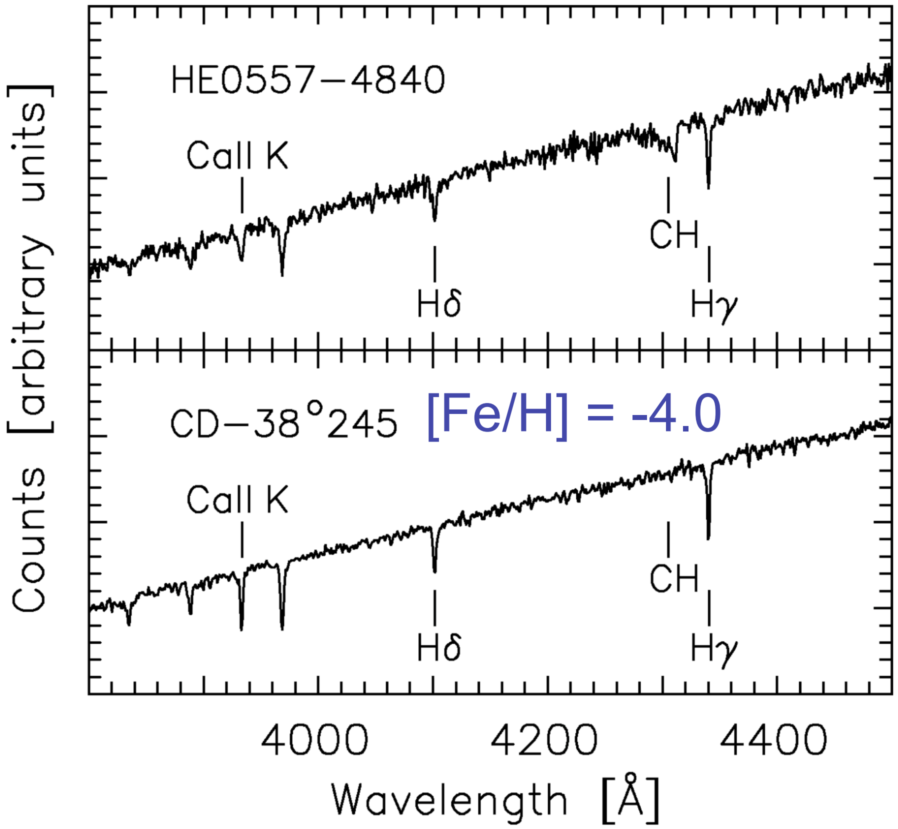
HE0107−5240
HE1327−2326
G77−61
CS29498−043
LP625−44
HD140283
CD−38 245
[C/Fe]
[N/Fe]
HE1327−2326(OH)
CS29498−043 ([OI]/OI)
HE0107−5240 (OH)
LP625−44 (OI)
CD−38 245 (OH)
OI,OH
[OI]
[O/Fe]
[Fe/H]

Magnesium (check out below [Fe/H] < -3.5)



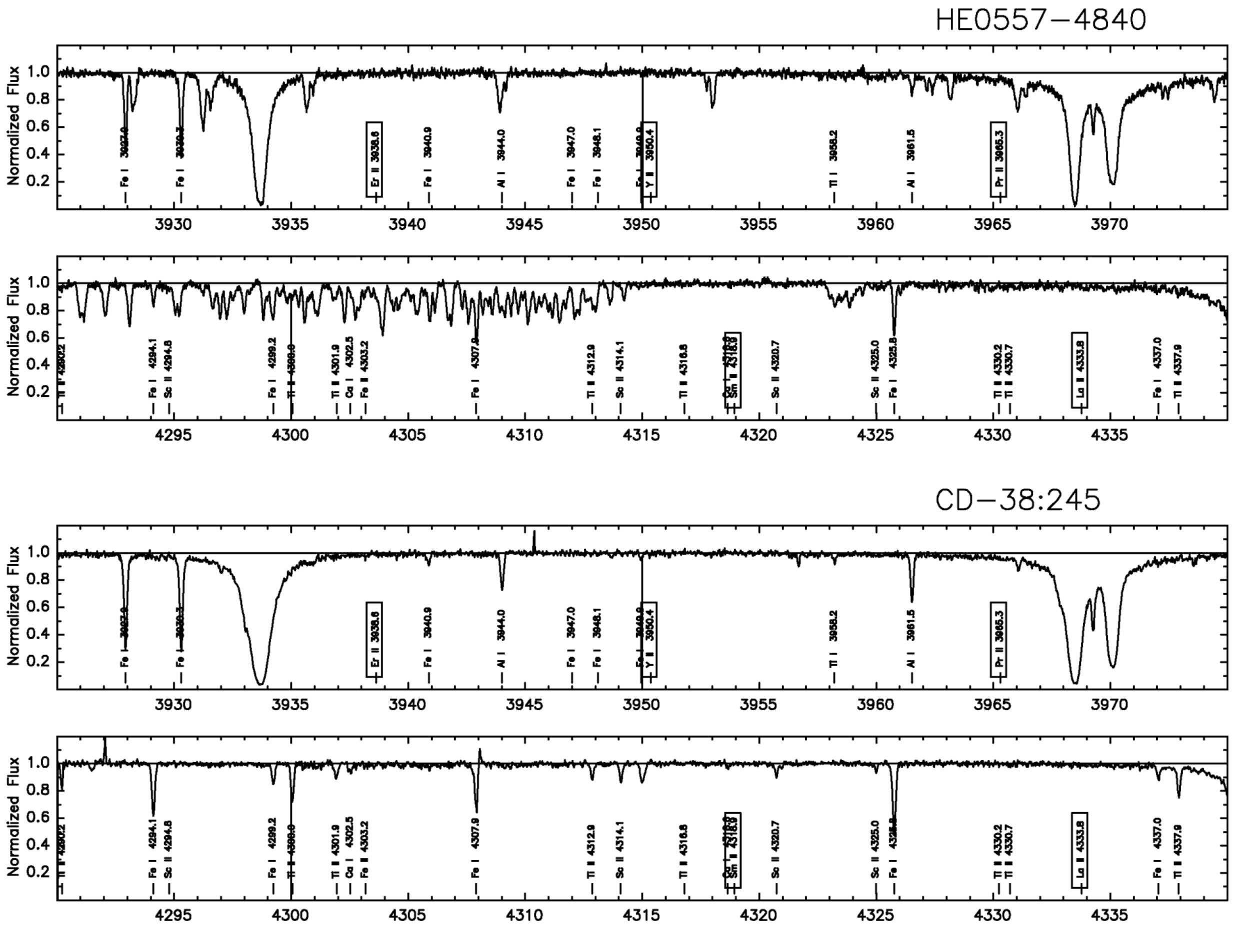
Aoki et al. 2006, ApJ, 639, 837

HE0557-4840 - Discovery (SSO 2.3m/DBS: R = 3000)



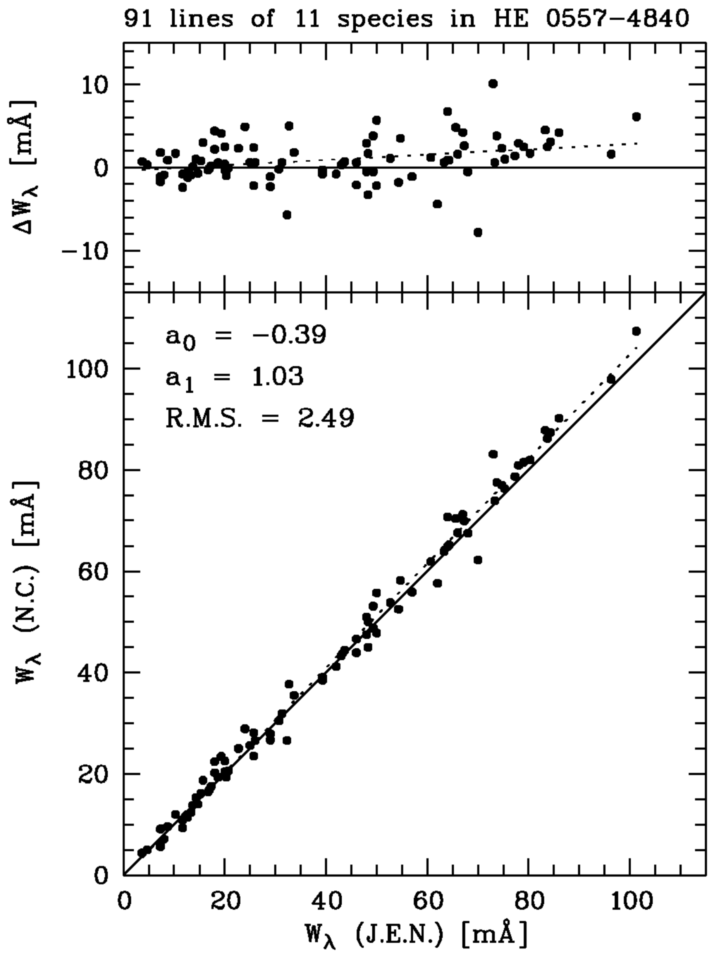
Norris et al. 2007, ApJ, in press

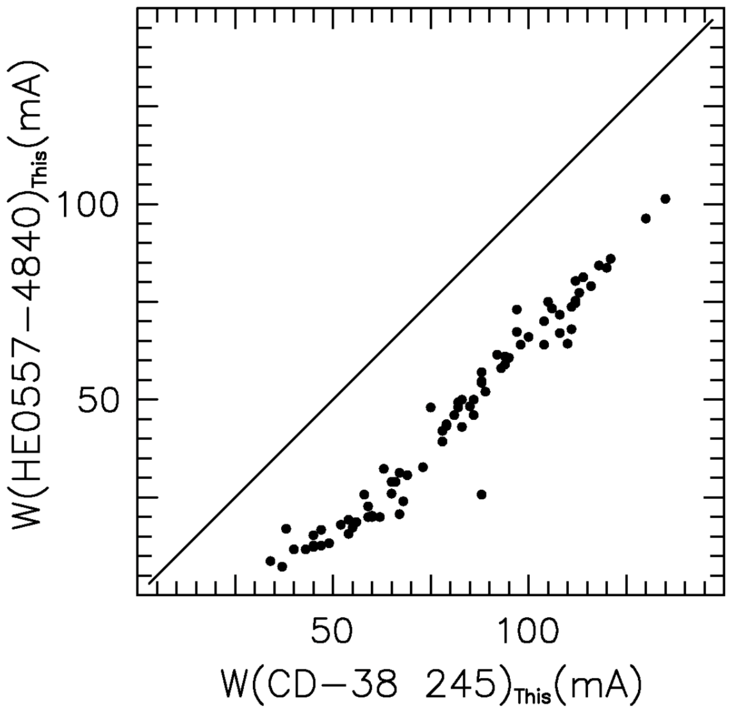
VLT/UVES DDT (R = 40,000, S/N = 120 at 4200A)



[Fe/H] = -4.0

Line strengths:





Norris et al. 2007, ApJ, in press

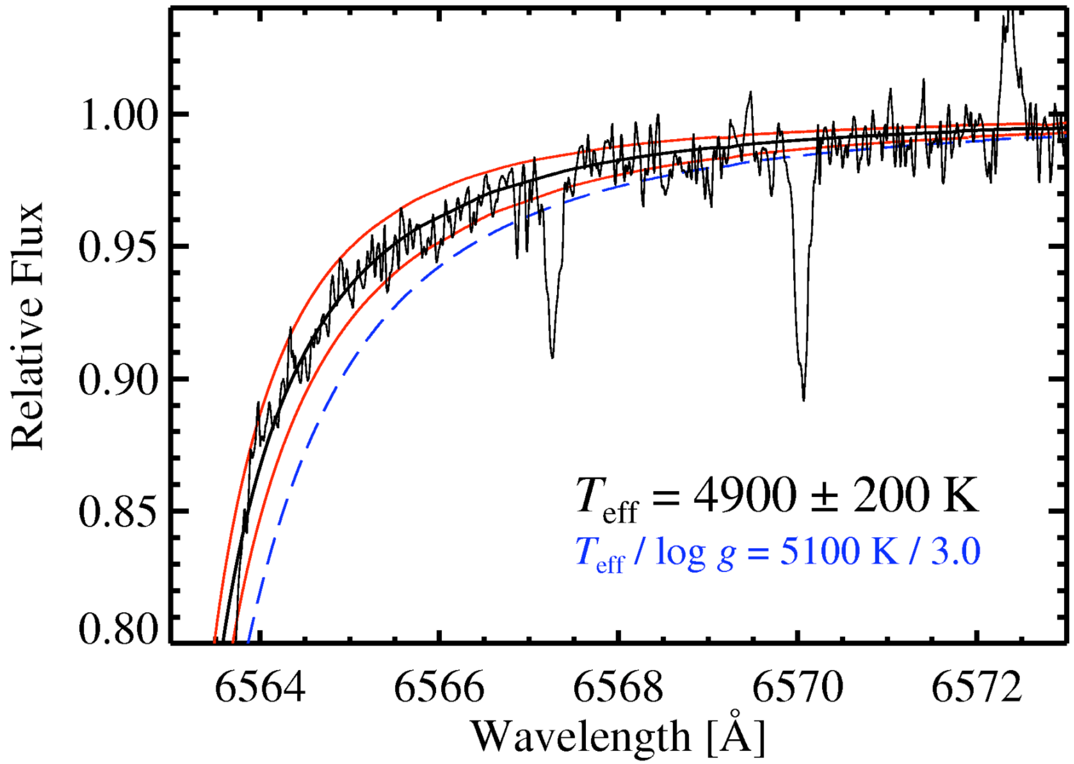
HE0557-4840 - atmospheric parameters

	Spect.	Photom.
T_{eff}(K)	4900	5100
log g	2.2	2.2
[Fe/H]	-4.8	-4.7
ξ_{micro}	1.8	1.8

Spect.: Hα

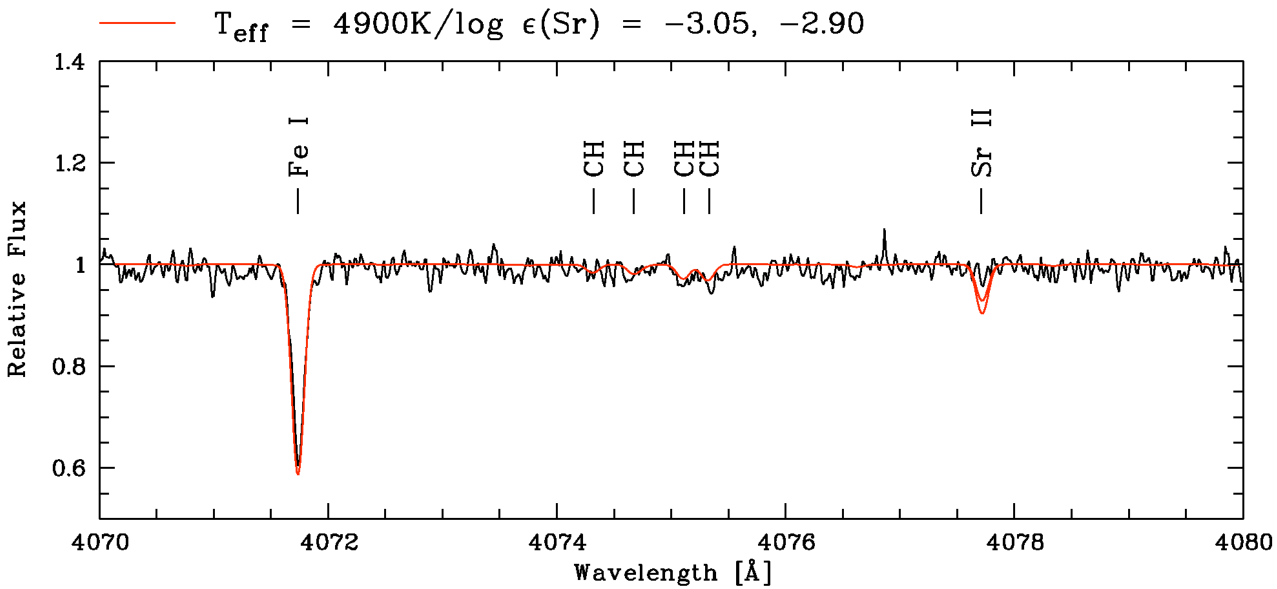
Photom.: B-V, V-R & J-K

HE0557-4840 - fitting Hα



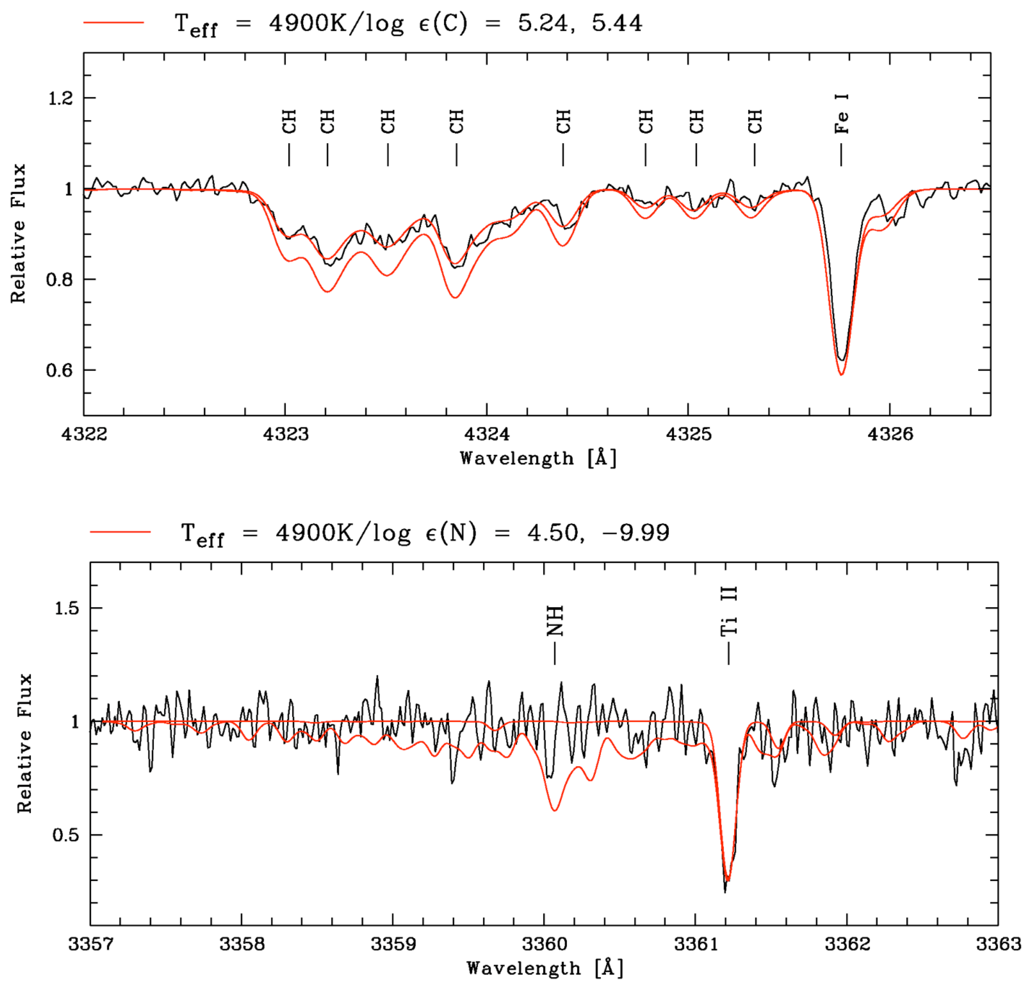
Norris et al. 2007, ApJ, in press

HE0557-4840 - Sr II limit



Norris et al. 2007, ApJ, in press

HE0557-4840



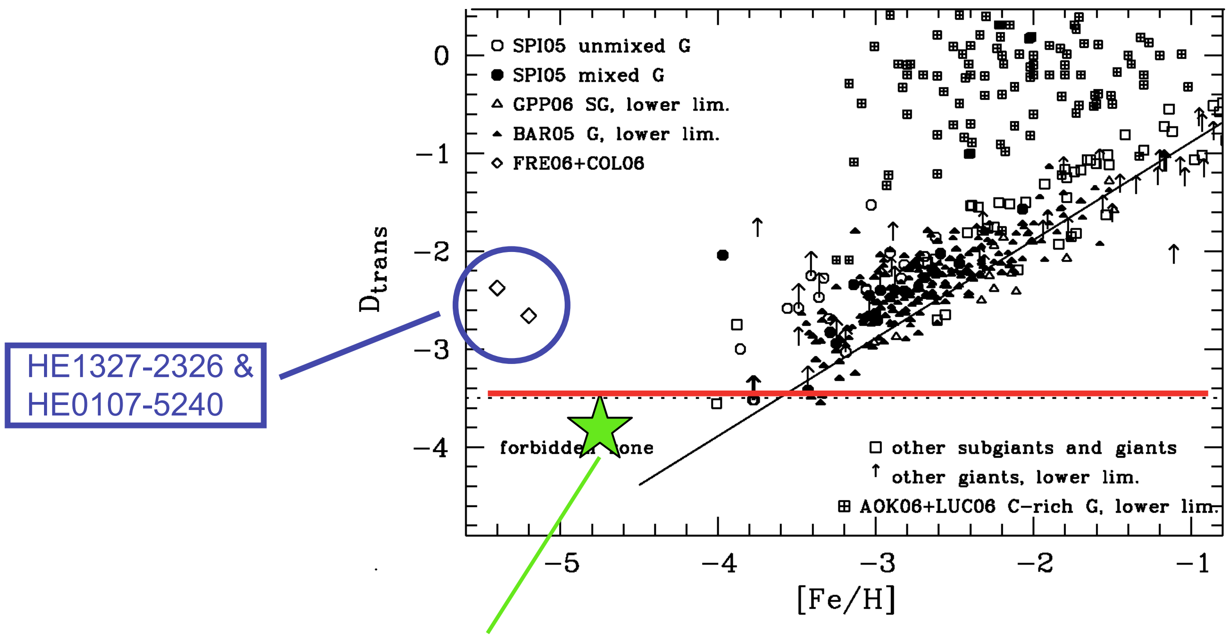
[C/Fe] = 1.6

[N/Fe] < 1.5

Norris et al. 2007, ApJ, in press

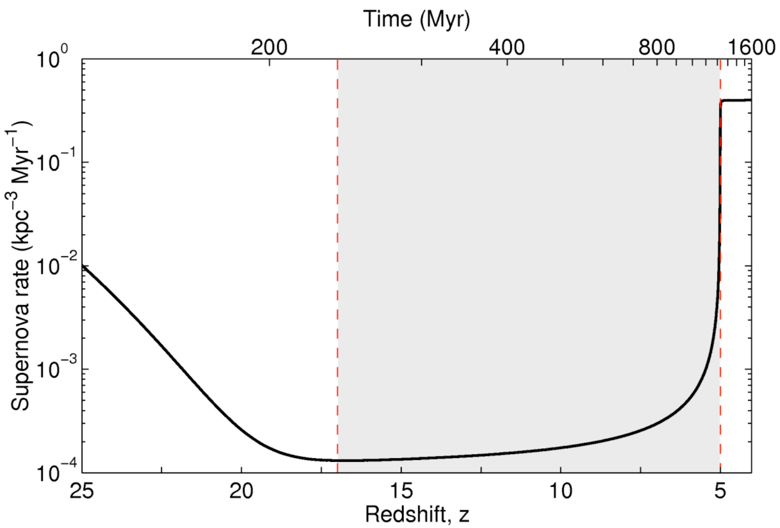
Frebel, Johnson & Bromm 2007, astroph/0701395

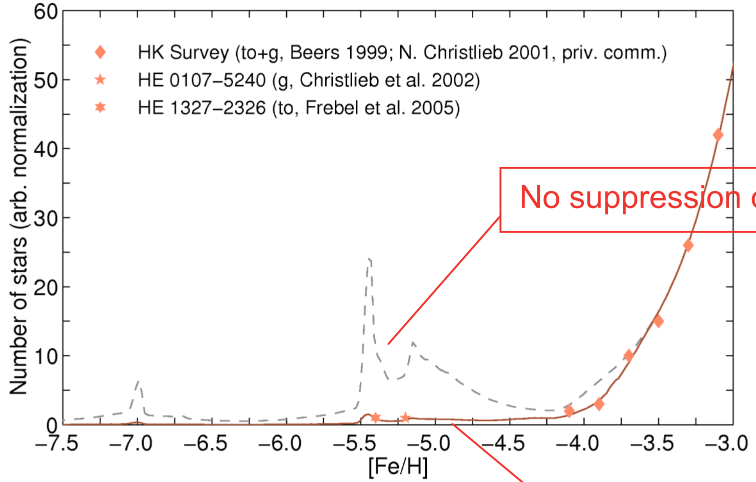
Condition for formation of low mass stars in the early Universe (with cooling by CII and OI fine-structure lines): $D_{trans} = \log_{10}(10^{[C/H]} + 0.3 \times 10^{[O/H]}) > -3.5$



$-4.1 < D_{trans}(\text{HE0557-4840}) < -3.5$

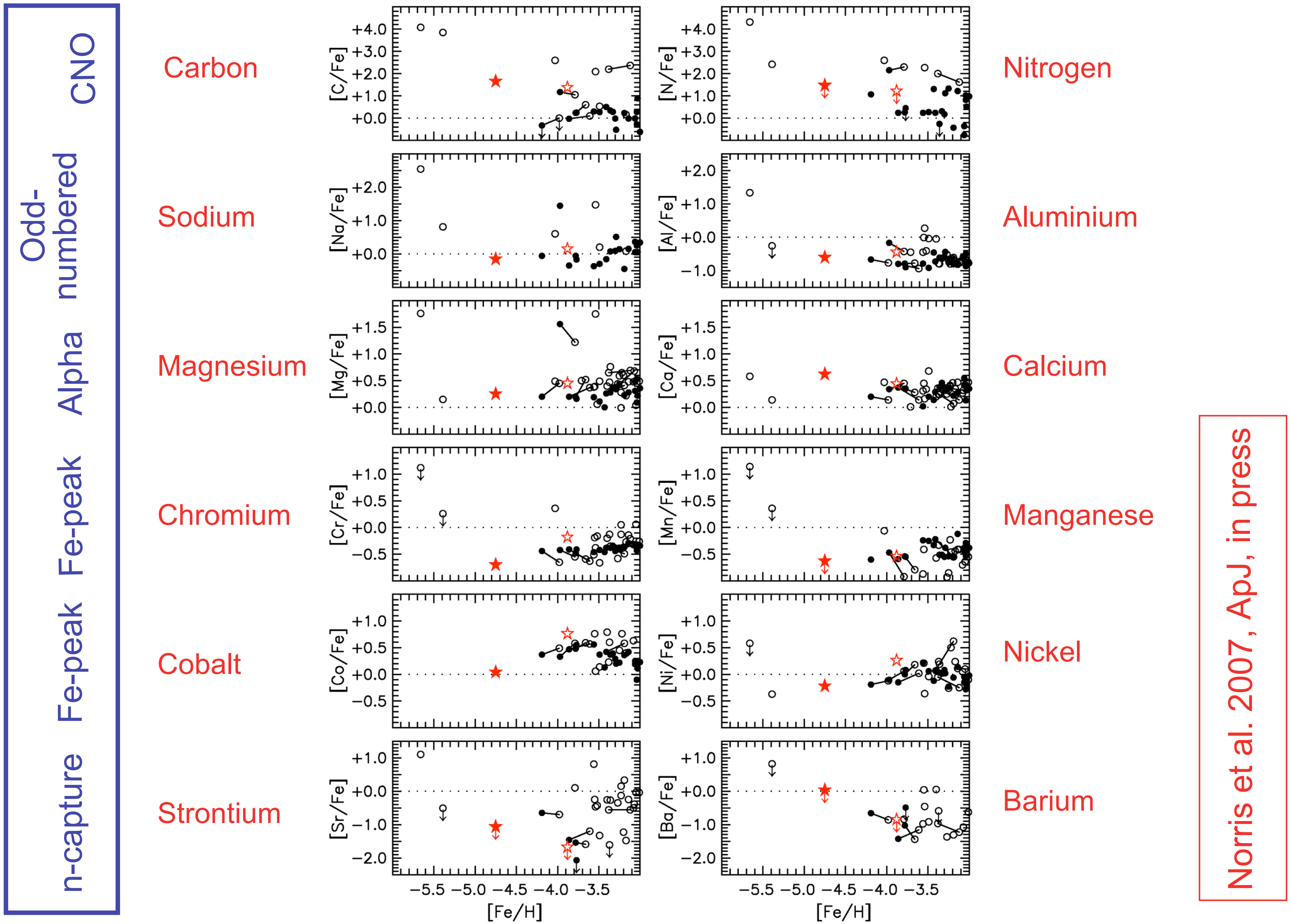
Karlsson 2006, ApJ, 641, L41





No suppression of formation of low-mass stars

Suppression of formation of low-mass stars, when [C/H] < -3.5


CNO
Odd-numbered
Alpha
Fe-peak
Fe-peak
n-capture
Carbon
Nitrogen
Sodium
Aluminium
Magnesium
Calcium
Chromium
Manganese
Cobalt
Nickel
Strontium
Barium
[C/Fe]
[N/Fe]
[Na/Fe]
[Al/Fe]
[Mg/Fe]
[Ca/Fe]
[Cr/Fe]
[Mn/Fe]
[Co/Fe]
[Ni/Fe]
[Sr/Fe]
[Ba/Fe]
[Fe/H]
Norris et al. 2007, ApJ, in press

POSSIBLE INGREDIENTS TO EXPLAIN ABUNDANCE PATTERNS OF THE CNO ENHANCED STARS WITH [Fe/H] < -3.5

- Nucleosynthesis and mass transfer in a first generation binary system, with subsequent accretion from a cloud containing supernova ejecta (Suda et al. 2004, ApJ, 611, 476 ; for HE0107-5240 predicts P_{orbit} ~ 150 yr with orbital velocity amplitude ~7 km s^{-1}).

- 250-500 $M_\odot$, Z = 0 first generation stars (e.g. Woosley & Weaver 1982; primary nitrogen); & with rotation (Fryer, Heger & Woosley 2001 ApJ, 550, 372; C, N, O & Mg enhancements [but not heavier elements?]

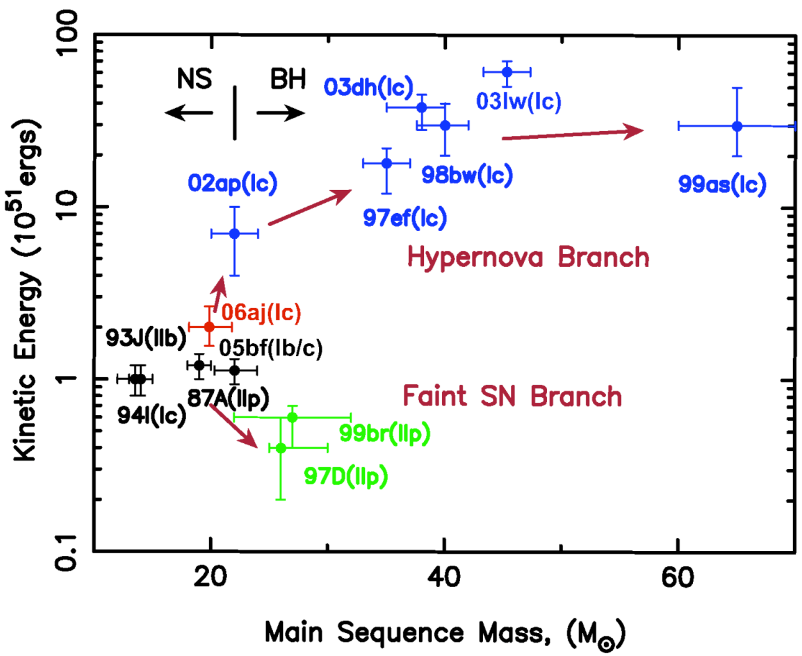
- Concurrent pollution by two supernova, one of which experienced strong fallback, causing CNO enhancements (Chieffi & Limongi 2003, A&A, 594, L123)

- 20-30 $M_\odot$, Z = 0 first generation "faint" supernovae (E_{51} < 1) with mixing and fallback (e.g. Umeda & Nomoto 2003, Nature, 422, 871; Iwamoto et al. 2005, Science, 309, 451)

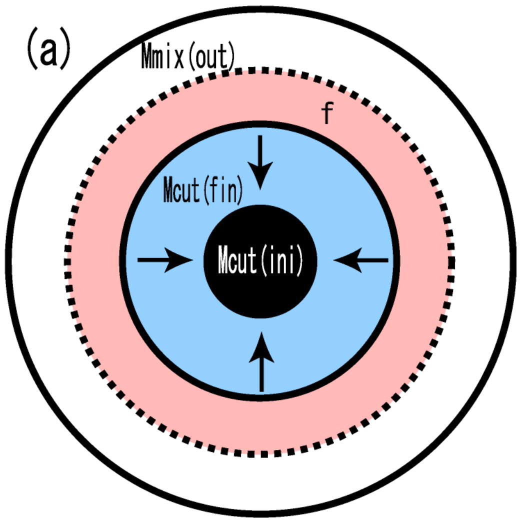
- Canonical evolution of rotating 60 $M_\odot$, Z = 0 stars (Meynet, Ekstrom & Maeder 2006, A&A, 427, 623; C, N, O, Na, Al enhancements)

Nomoto et al. 2006, astro-ph/0605725

Hypernovae and "faint" supernovae

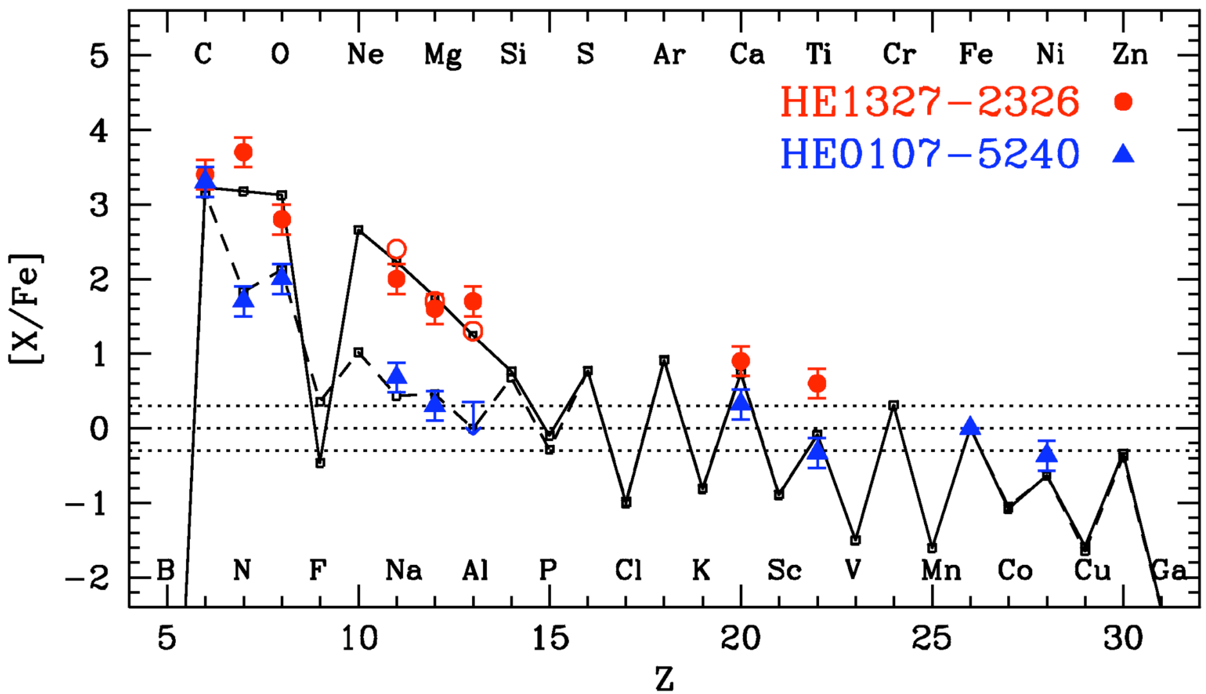


Mixing and fallback



Mixing and Fallback SNe

Iwamoto et al. 2005, Science, 309, 451



but … HE0557-4840 has [Cr/Fe] = -0.7 & [Co/Fe] = 0.0

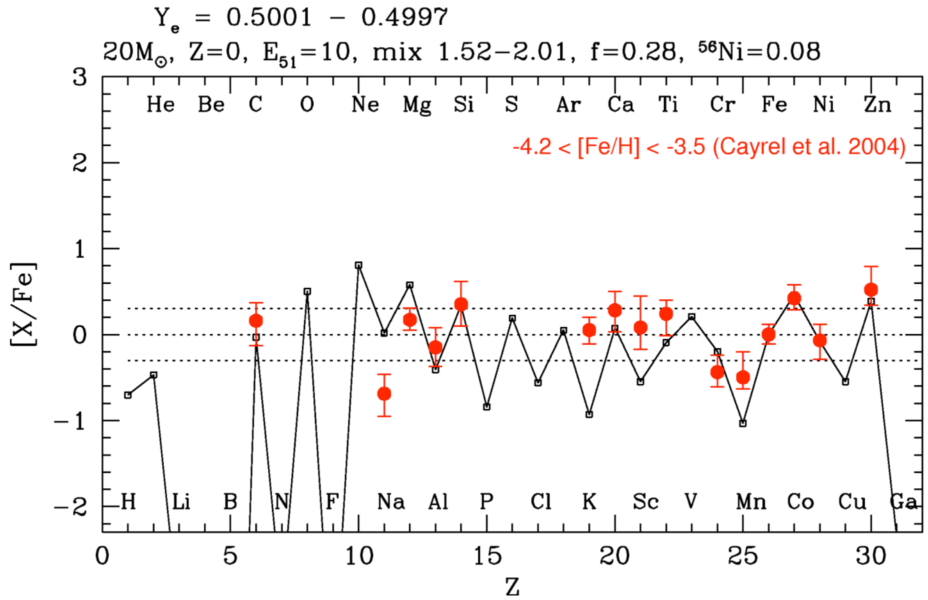
Enrichment by two events

(see Frebel et al 2007, ApJ, 658, 534 for HE1300+0157):

- Massive, slowly rotating Population III object (M > $100M_\odot$, Z = 0), which produces C and O, but little N and heavier elements before exploding as a pair-instability SN (e.g. Heger & Woosley 2002, ApJ, 567, 532)

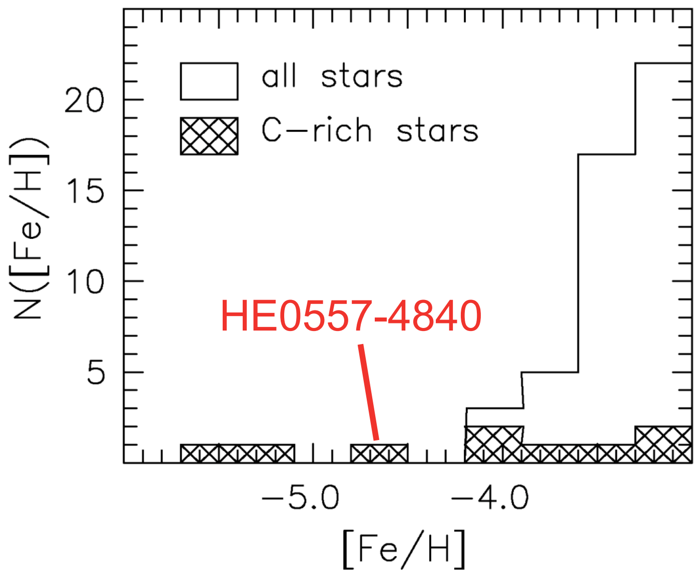
+

- Hypernova with M ~ $20M_\odot$ Z = 0, E = 10 x 10^{51} ergs, which contributes elements having atomic number less than 30 (e.g. Umeda & Nomoto 2005, ApJ, 619, 427, Nomoto et al. 2006, astro-ph/0605725)



The latter predicts [Co/Fe] = 0.4, while HE0557-4840 has [Co/Fe] = 0.0 ($[Co/Fe]_{3D}$ = -0.3)

Summary



- HE0557-4840 has T_{eff}(K) = 4900K, log g = 2.2, [Fe/H] = -4.8, & [C/Fe] = +1.6
- It lies in the putative "gap" between [Fe/H] = -4.0 and -5.5
- All three stars with [Fe/H] < -4.0 have [C/Fe] > +1.0, suggesting that carbon richness may be a necessary requirement for formation of low mass stars at the earliest times
- Apart from [C/Fe], and possibly [Co/Fe], measured relative abundances [X/Fe] of HE0557-4840 are similar to those of the majority fraction of material with [Fe/H] < -3.5
- Existing "mixing and fallback" models provide poor explanation of relative abundances, while a two component model provides a better, but still inadequate one