NEW BERYLLIUM RESULTS IN HALO STARS FROM KECK/HIRES SPECTRA

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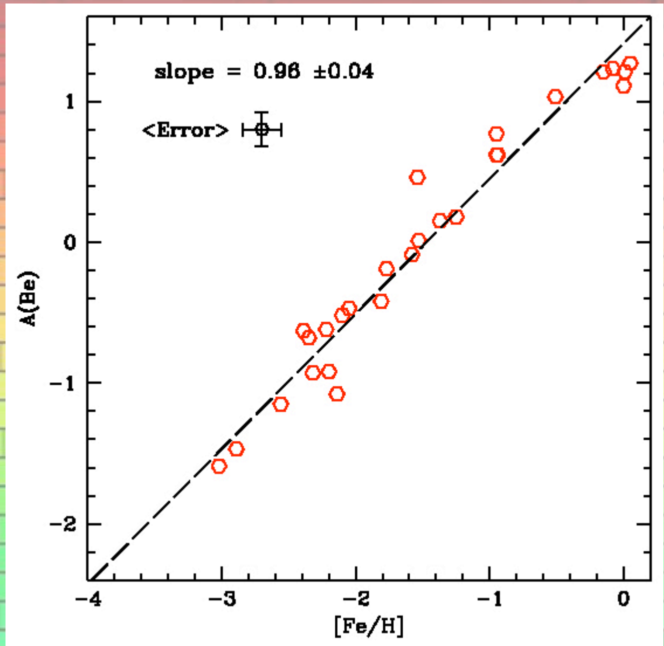
KECK+HIRES SPECTRA of Be II – 1993-2008

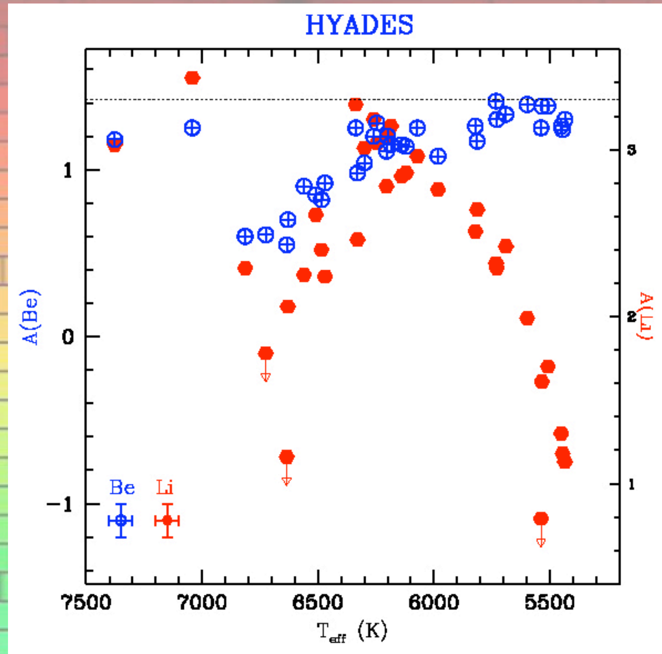
1993 – 2003	2004 – 2008
"Engineering" chip	3 CCDs: B, G, R
Q.E. ~ 8% at 3130 Å	Q.E ~ 93% at 3130 Å
BD +3 740 V = 9.81	BD +3 740 V = 9.81
Exp. 10^h S/N = 176	Exp. 1^h S/N = 167
BD -13 3442 V=10.26	BD -13 3442 V=10.26
Exp. 11^h S/N = 129	Exp. 1^h 20^m S/N = 183

Early Be Results from HIRES



Be in Halo Stars
A(Be) = 0.96 [Fe/H] + 1.41

Boesgaard et al. (1999)

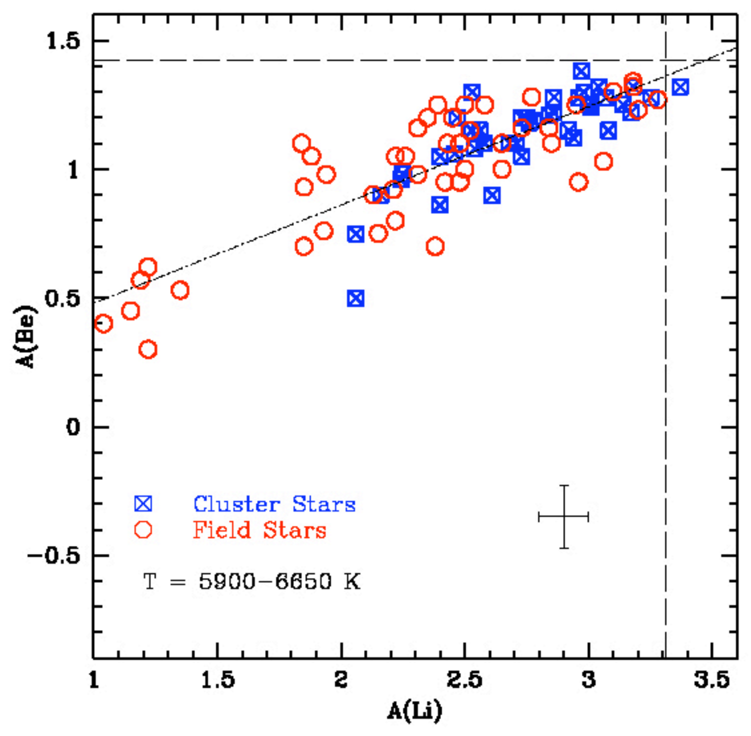


Discovery of a Be dip in the Hyades Li Dip region. Also studied Be in Pleiades, UMa, Coma, Praesepe, ά Per

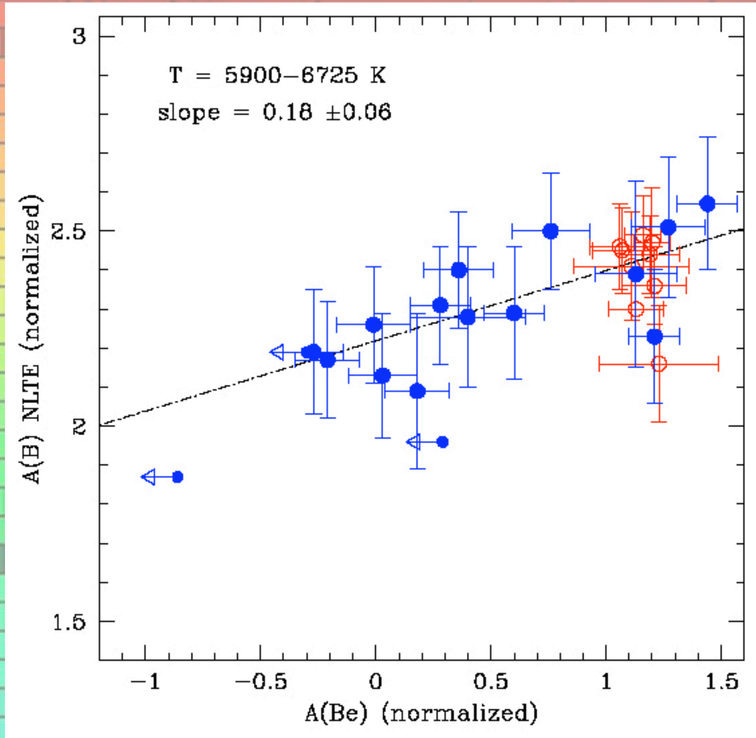
Boesgaard & King (2002)

Correlated Depletions

Li and Be



Be and B



Best explained by mixing due to stellar rotation

Boesgaard et al. (2004)

Boesgaard et al. (2005)

HIRES Upgrade – summer 2004

3 CCDs 2048 x 2048 15μ pixels

We received 16 nights for Be over 41 months on Keck I with the new HIRES

Lost 2 nights:

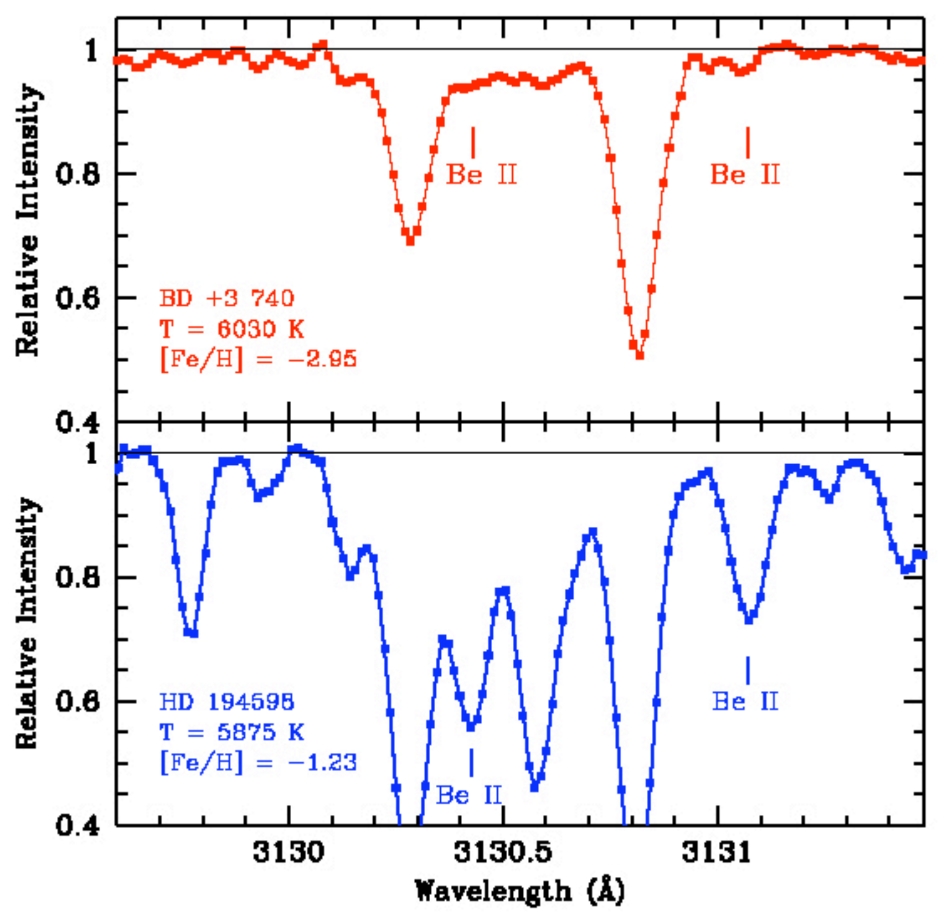
March 19, 2006 – <u>Snow!</u>

October 15, 2006 – 6.7mag. <u>Earthquake!</u>

12 good nights for several Be programs

+ 2 marginal nights: some fog, clouds

Spectra in the Be II region

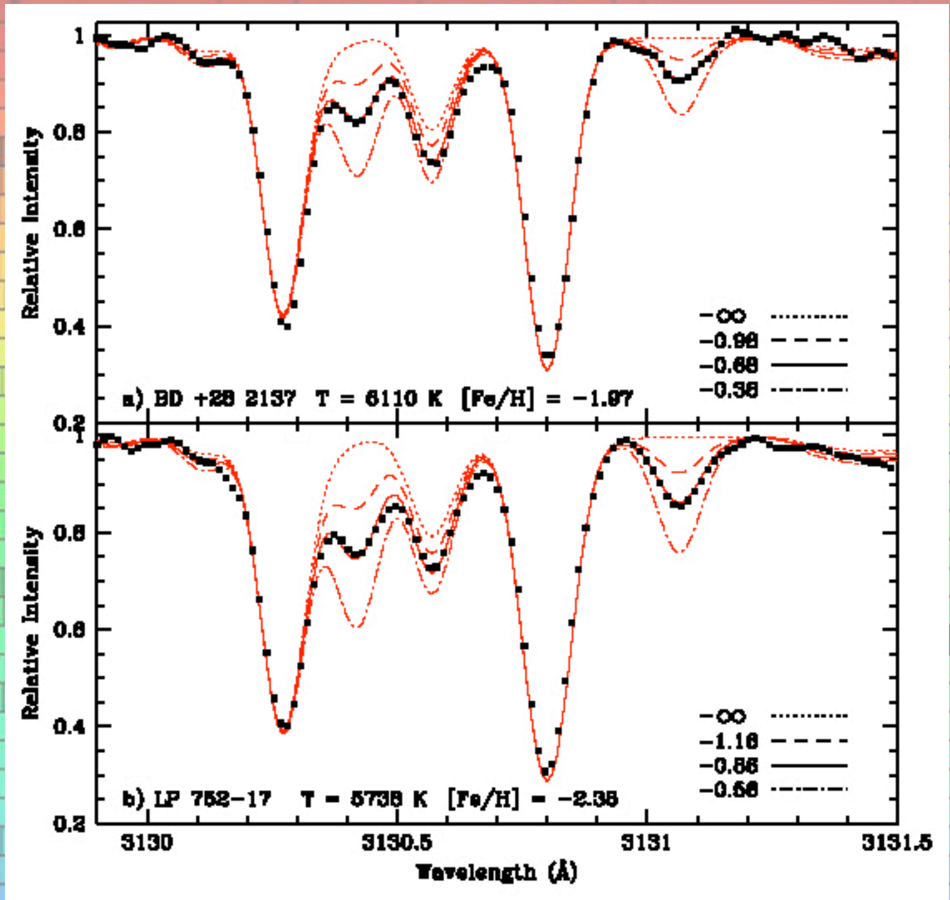


BD +3 740
[Fe/H] = –2.95
Weak Be Lines

HD 194598
[Fe/H] = –1.23
Clear Be lines

Rich & Boesgaard 2009

Stellar Spectrum Synthesis Method



Rich & Boesgaard 2009

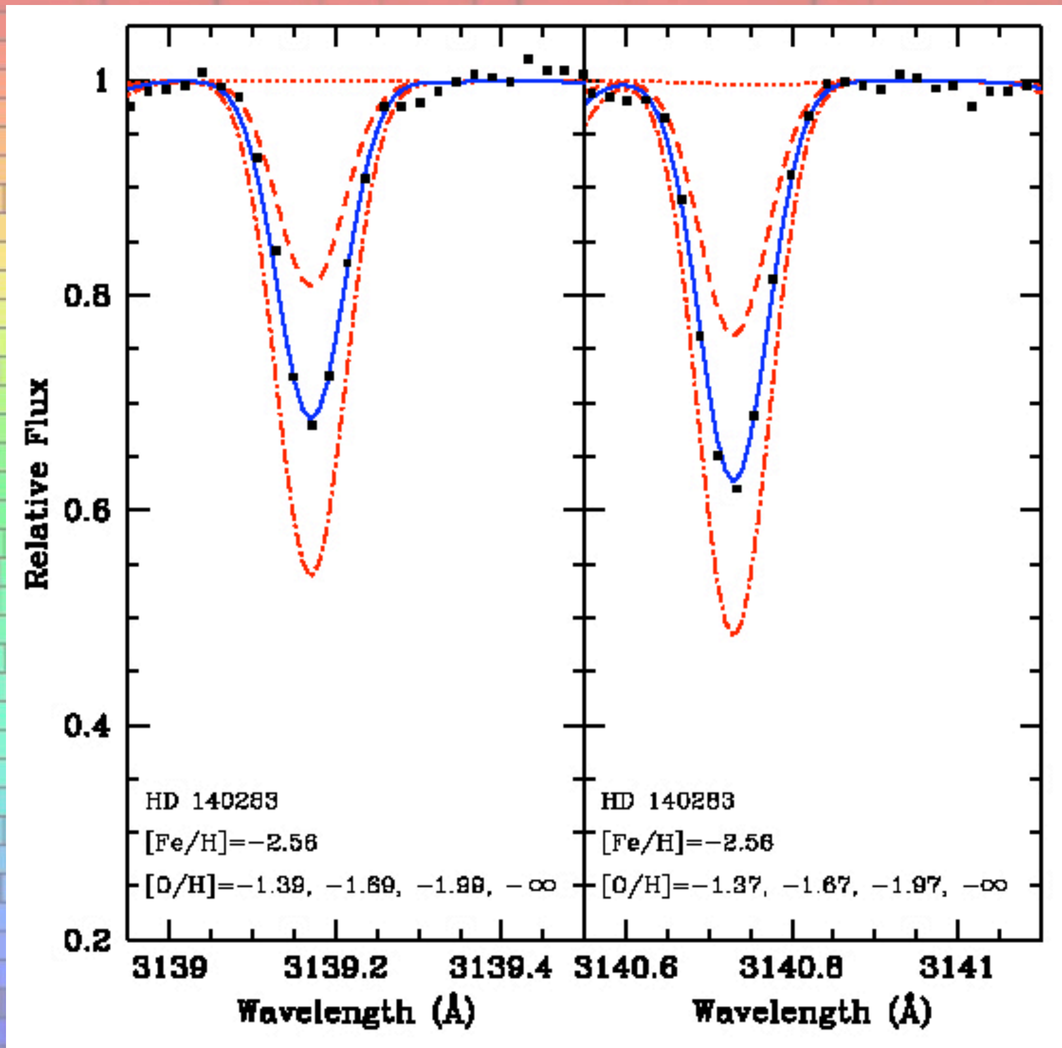
Parameters determined spectroscopically from Fe I, Fe II, Ti I, Ti II lines.

T_{eff} = 5550 – 6400 K
log g = 3.2 to 4.9
[Fe/H] = –0.5 to –3.5
ξ = 0.9 to 1.5 km/s

Change Be by ±0.30 dex

And O by ±0.10 dex

Oxygen from 3 OH lines



OH lines

3130.6

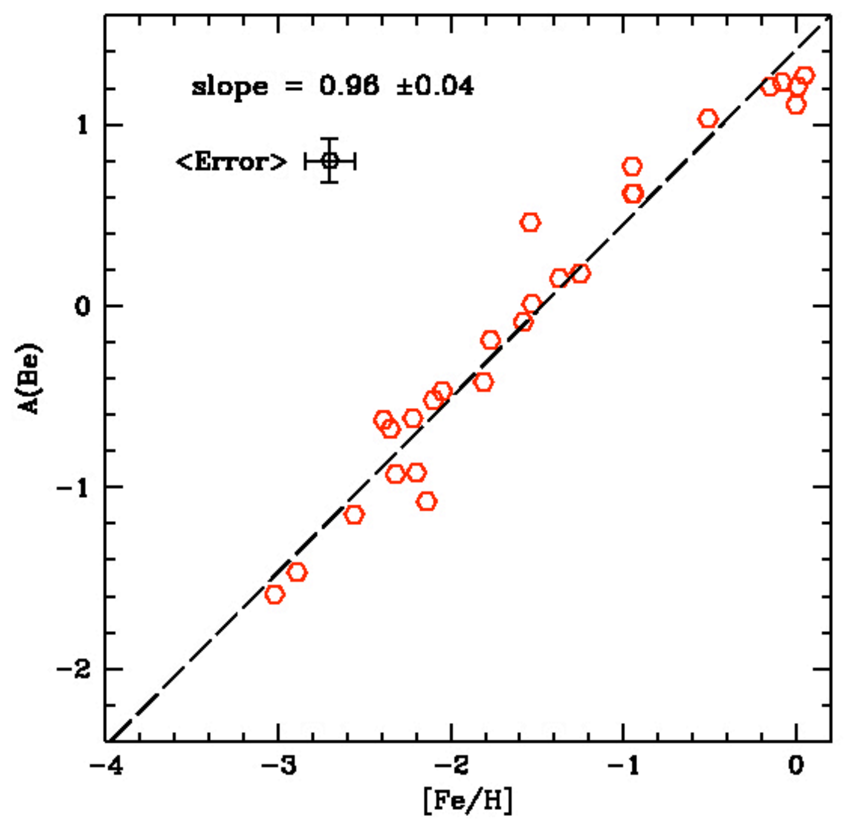
3139.2

3140.7

1-D vs 3-D

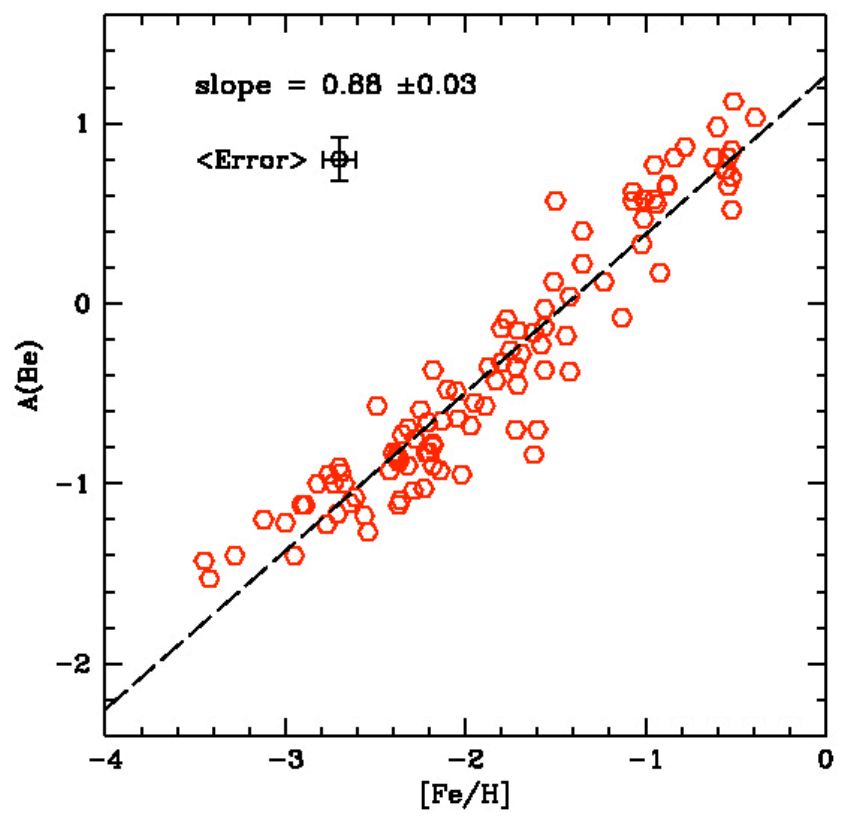
A(Be) vs [Fe/H]

1999

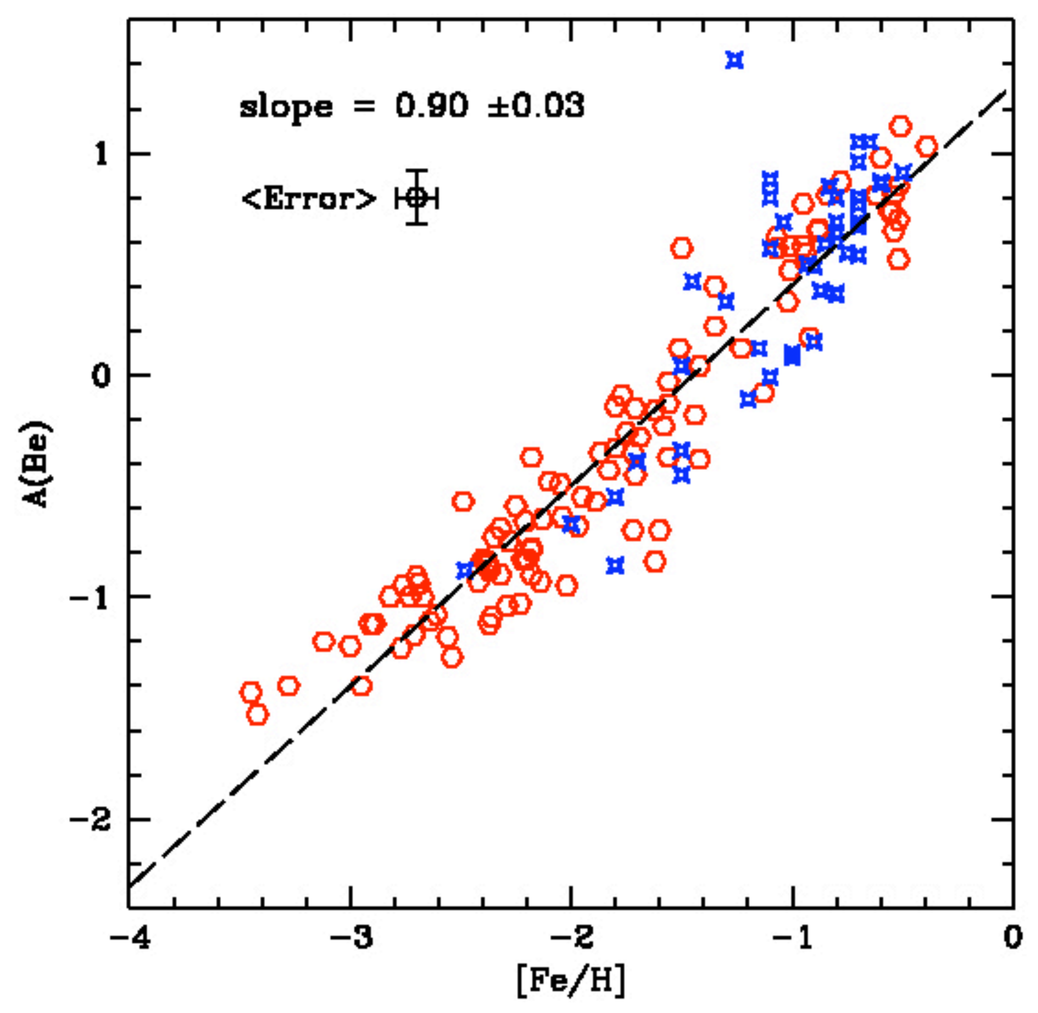


Boesgaard et al. (1999)

2009

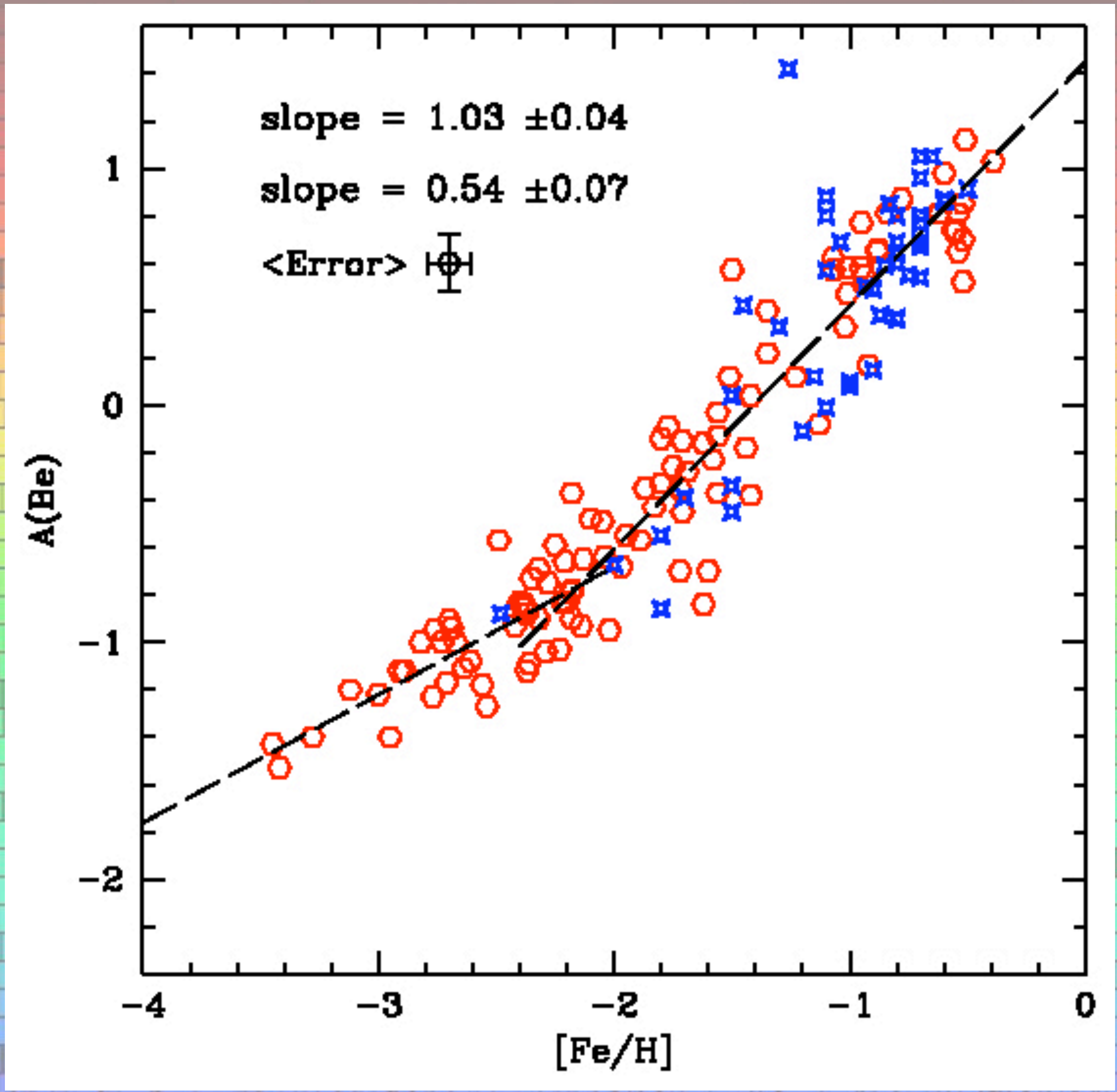


Rich & Boesgaard (2009)



Includes the stars from Smiljanic et al. (2009) with parameters determined spectroscopically

Slope = 0.90 ± 0.03

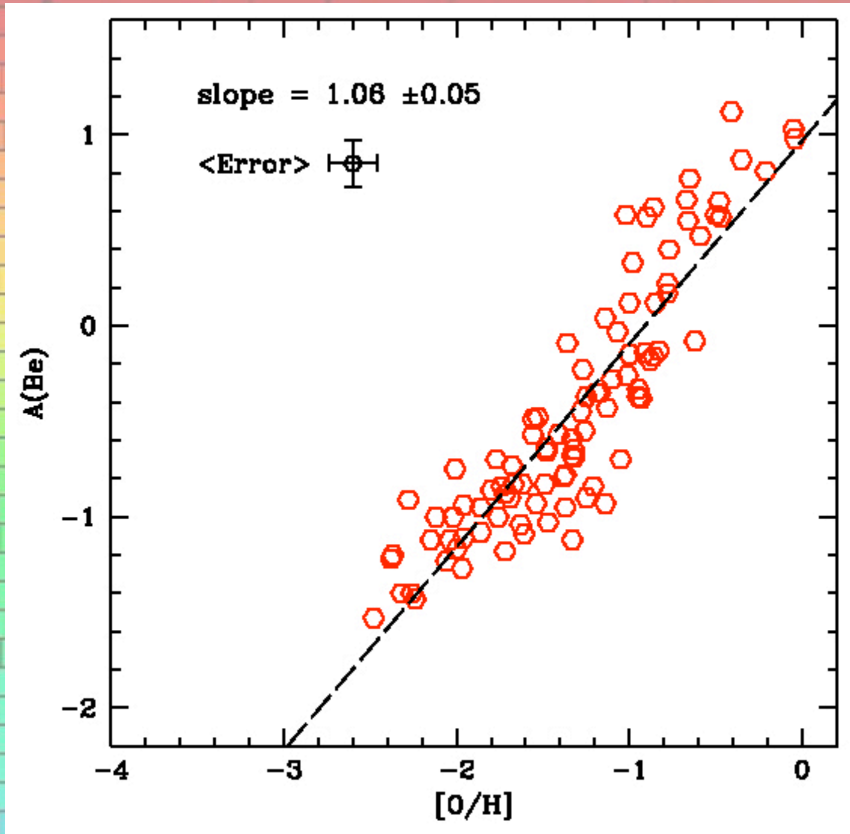


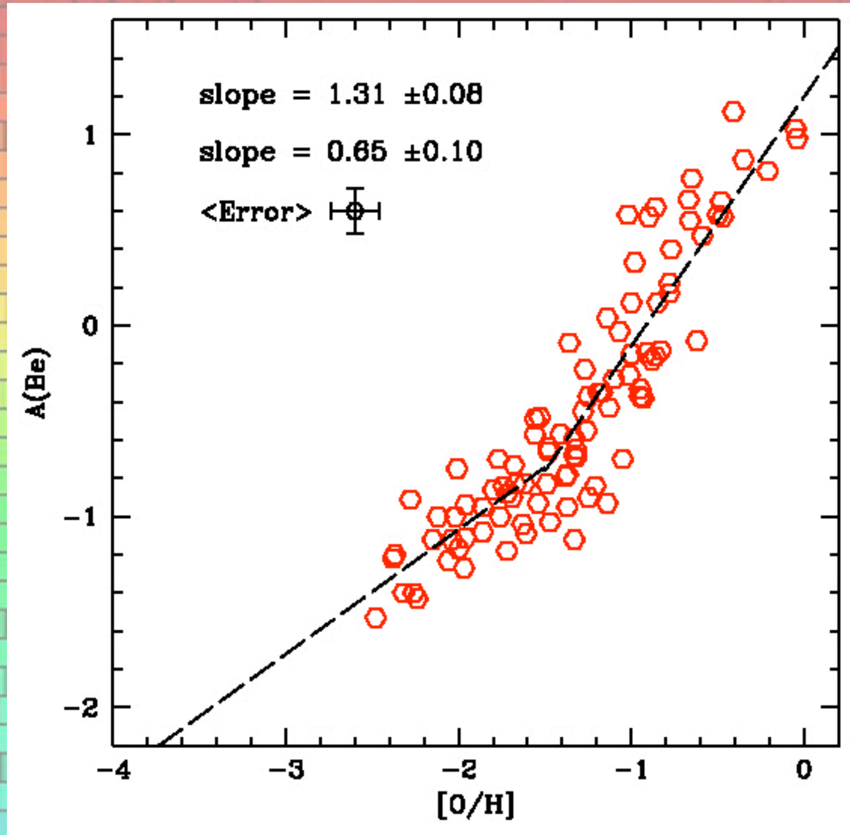
2 slope fit

High Fe stars:
[Fe/H] > –2.2
slope = 1.03

Low Fe stars:
[Fe/H] < –2.2
slope = 0.54

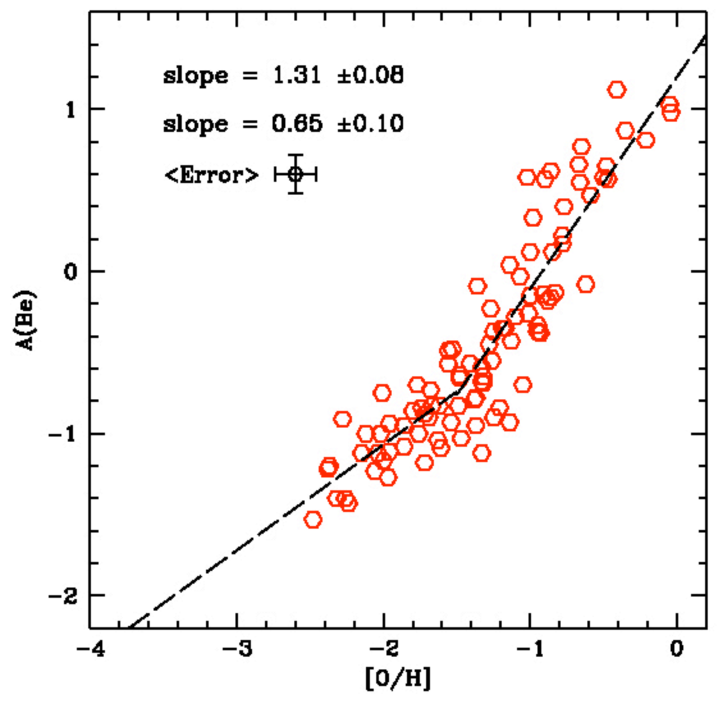
A(Be) vs. [O/H]


slope = 1.06 ±0.05
<Error>
A(Be)
[O/H]
1
0
−1
−2
−4
−3
−2
−1
0


slope = 1.31 ±0.08
slope = 0.65 ±0.10
<Error>
A(Be)
[O/H]
1
0
−1
−2
−4
−3
−2
−1
0

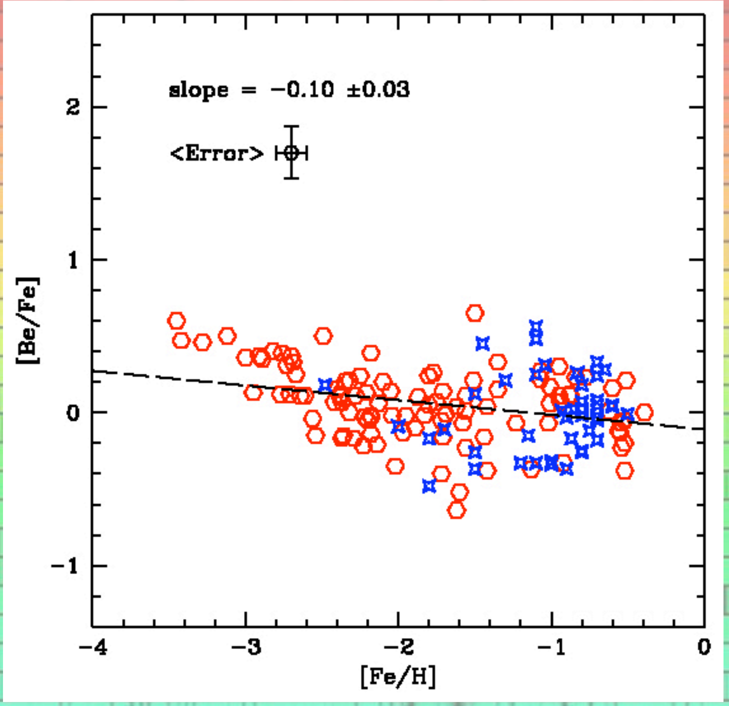
A change in slope is expected

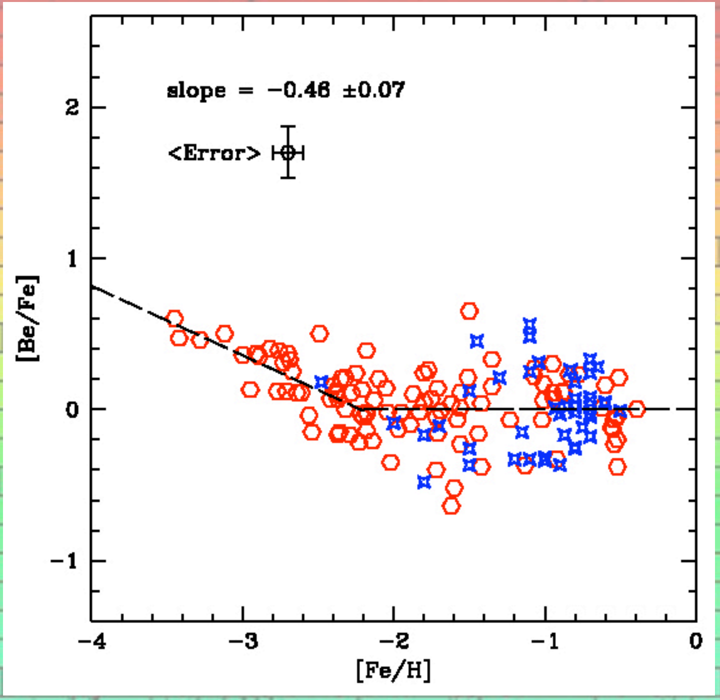
In the oldest stars Be would be formed mostly In the vicinity of SN II by acceleration of CNO atoms into protons etc. Be would be proportional to the instantaneous number of SN and thus proportional to O.
slope ≤ 1



In the younger stars Be would be formed by GCR spallation into the ISM. The number of O atoms would depend on the cumulative number of SN II (*N*). The number of energetic cosmic rays is proportional to the instantaneous rate of SN II (*dN*) The abundance of spallation products is $\int N\, dN = kN^2$.
slope ≤ 2

Is there a Be plateau at low Fe?

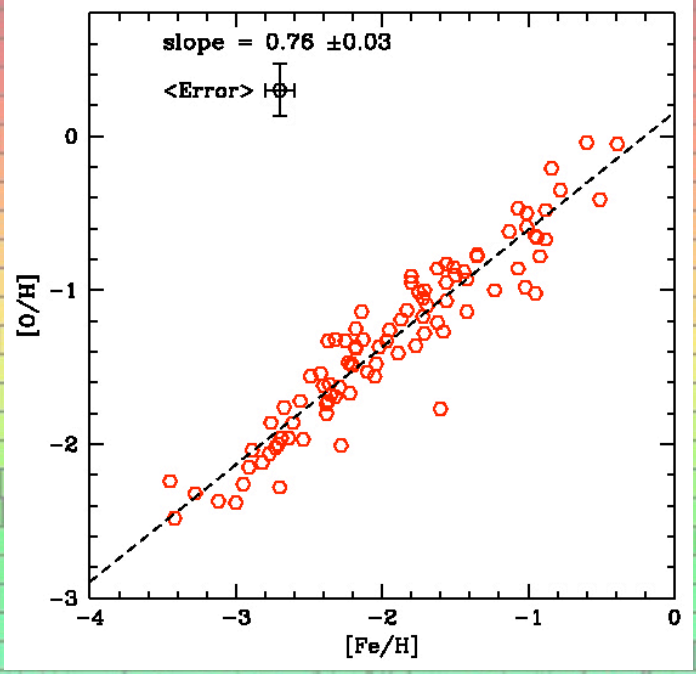


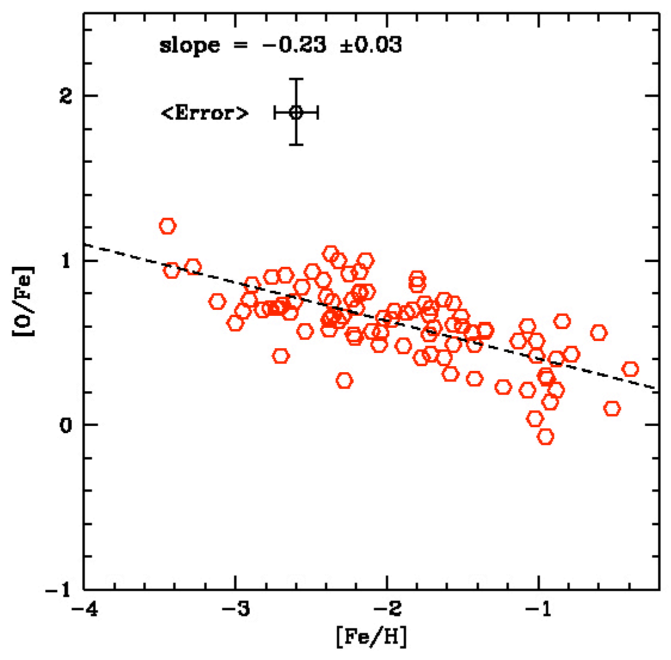


Not a "plateau"   A steady change

Another indicator of a change in slope

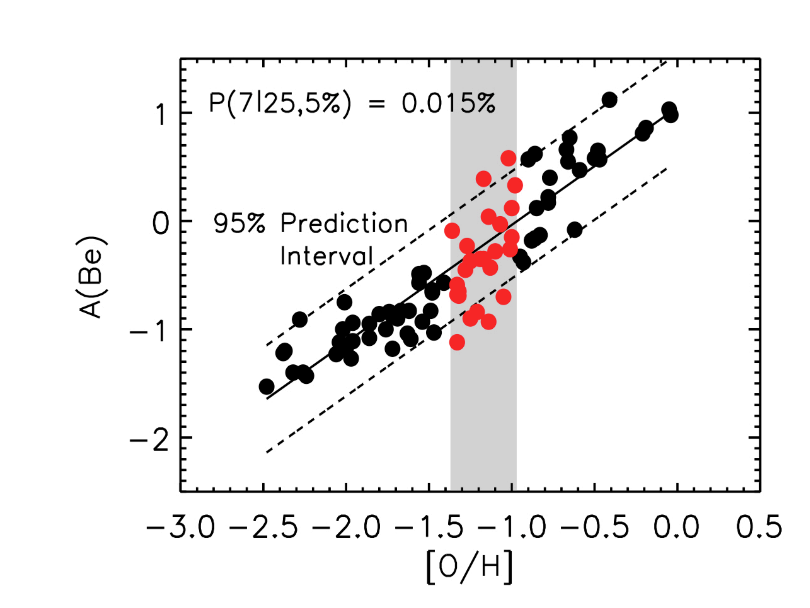
Oxygen and Iron Relationships

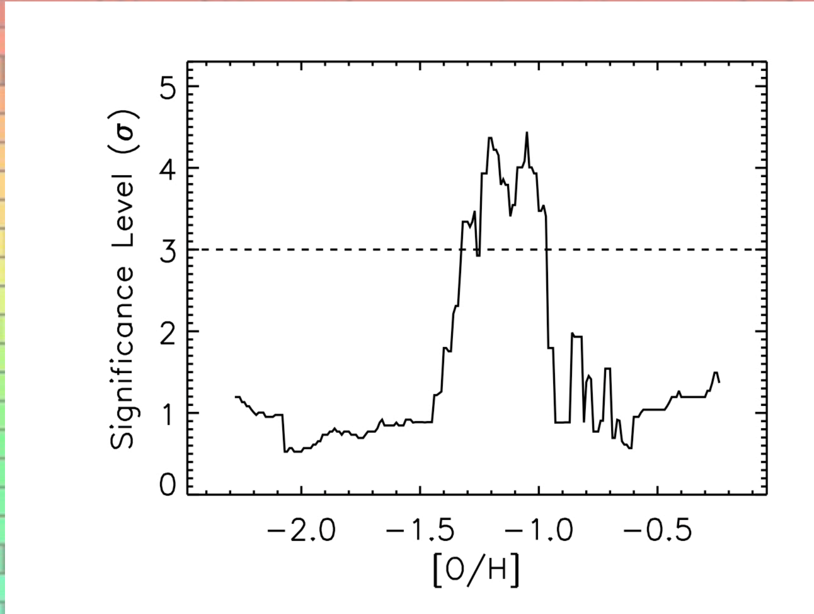




- A tight relationship between Fe and O from the UV lines of OH
- [O/Fe] shows smooth decline from [Fe/H] of –3.5 to –0.5

Is there a real spread in Be at a given [Fe/H] or [O/H]?



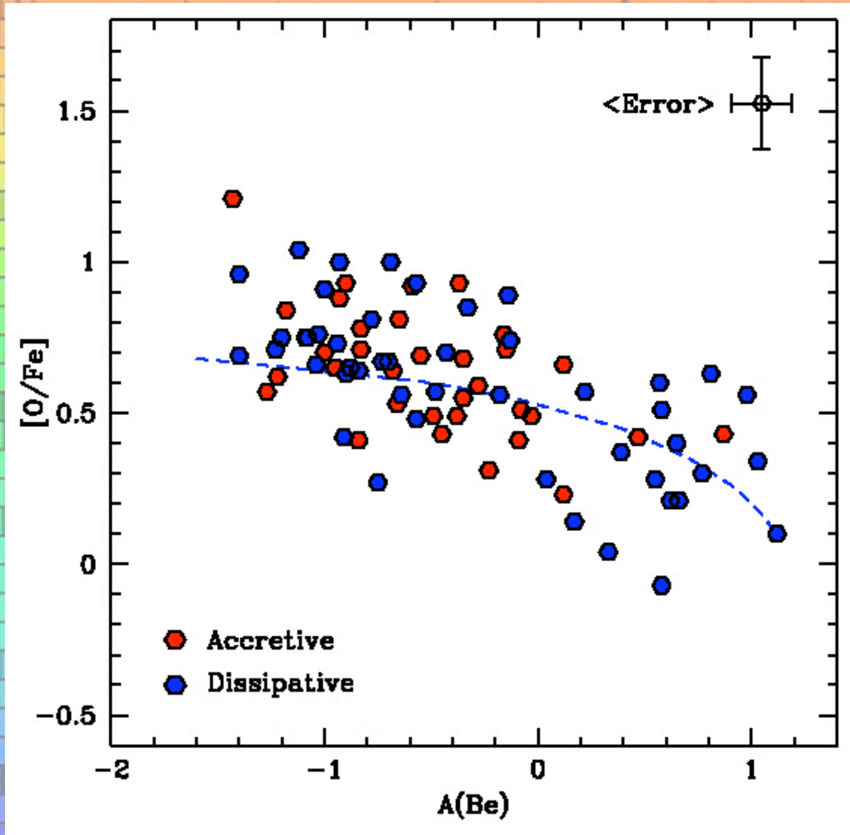


We did statistical tests using a prediction interval. Example: What is the probability that 7 out of 25 stars fall outside of the 95% prediction interval by chance? 0.015%

Accretive vs Dissipative

DISSIPATIVE: Formed in the early collapse of the Galaxy

ACCRETIVE: From Infalling proto-galactic fragments after the collapse



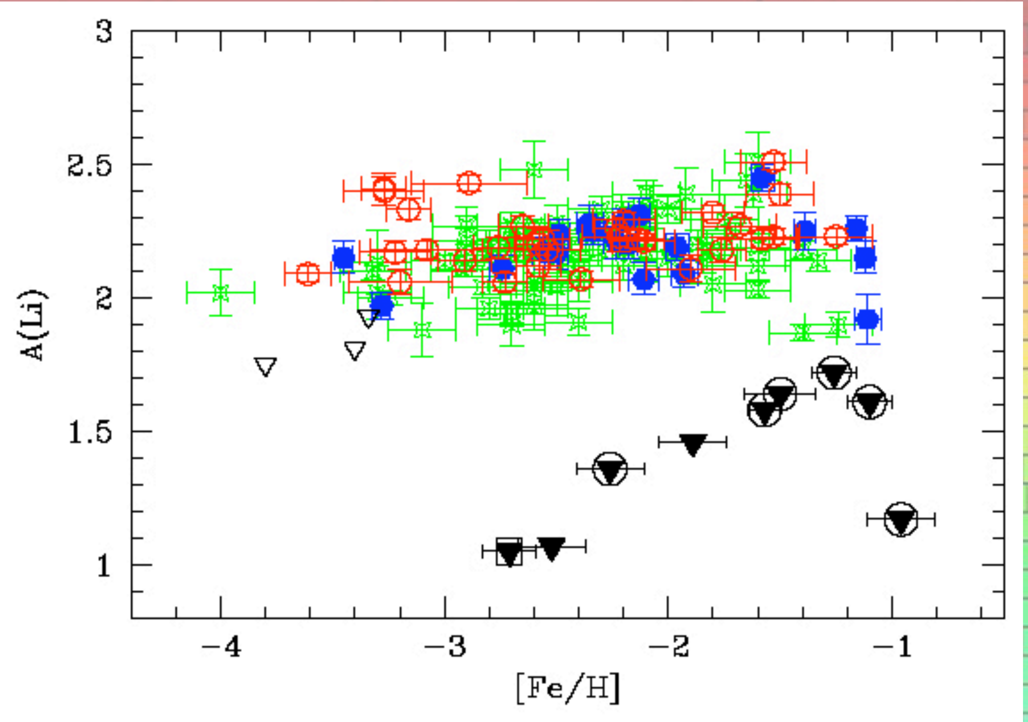
Gratton et al. (2003) Criteria:

Accretive	Dissipative
|	|
Non-rotating and Counter rotating	R_{apo} < 15 kpc v_{rot} > 40 km/s

Pasquini et al (2005) found that the model fit the dissipative stars and the accretive stars show a large scatter in the plot of [O/Fe] vs A(Be)

Here we see little difference in the distribution of the two components

Be in Ultra Li-Deficient Stars



Li plateau stars

A(Li) ~ 1.9 – 2.5

Ultra Li-Def stars

A(Li) < 1.7

Only upper limits

At least 2 possible causes:

- **Blue straggler analogs**
- **Rotationally induced mixing**

Ryan et al 2001, 2002
Pinsonneault et al 1999, 2002

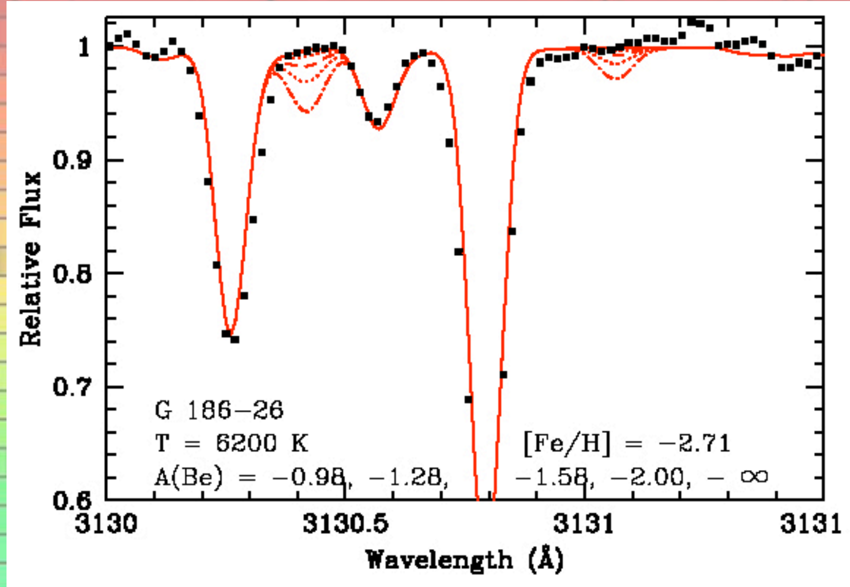
The theories for Li deficiencies make different predictions for Be

Blue straggler analog:

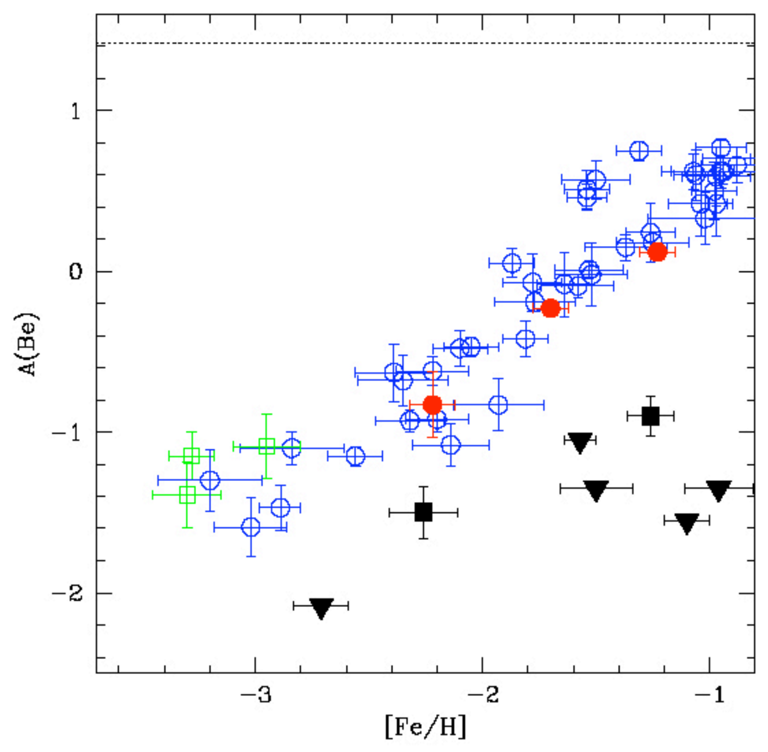
- All or most of Be would be <u>destroyed</u>
- Mass transfer or binary coalescence

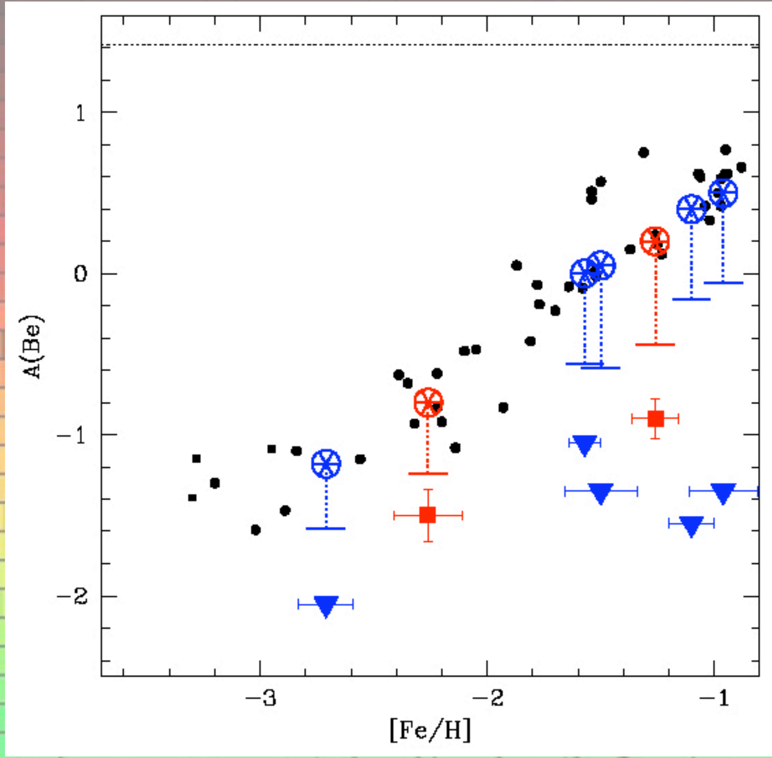
Mixing due to rotation:

- All or most of Be would be <u>preserved</u>
- Subset of rapid rotators deplete Li as they spin down



Example of Be spectrum of a Li-deficient halo star
G 186-26 [Fe/H] = –2.71
A(Li) < 1.1
A(Be) < –2.0





The Li-deficient stars are also Be-deficient

Models of Be depletion due to rotation predict too little depletion.

☻Blue straggler predictions: Most or all Li and Be gone

SUMMARY OF KECK BE RESULTS

- Correlated Depletions: Li and Be
  Be and B
- Be dip like Li dip in open clusters
- Halo Star Correlations: A(Be) vs [Fe/H]
  A(Be) vs [O/H]
  [Fe/H] vs [O/H]
- Two slope fits for Be vs Fe and Be vs O
  Older stars show shallower slope
- Real spread in Be at a given Fe and O
- Be is deficient in Li-deficient halo stars
  Mass transfer or binary coalescence