
データベースで探る銀河系の化学進化

THE STELLAR ABUNDANCES FOR GALACTIC ARCHAEOLOGY (SAGA) DATABASE

<http://saga.sci.hokudai.ac.jp/>

須田 拓馬 (北海道大学)

共同研究者

山田 志真子、勝田 豊、石塚 知香子、藤本 正行 (北海道大学)

西村 高德 (国立天文台)

CONTENTS

- Observations of Extremely Metal-Poor (EMP) stars
- The SAGA database
- Origin of most iron-poor stars
- Lessons from binary hypothesis
- Possible evidence for massive star binaries

銀河の化学進化

- 金属量は時間と共に増加

金属量の少ない星(金属欠乏星)
=古い世代の星

主系列星

原始星

分子雲

赤色(漸近)巨星

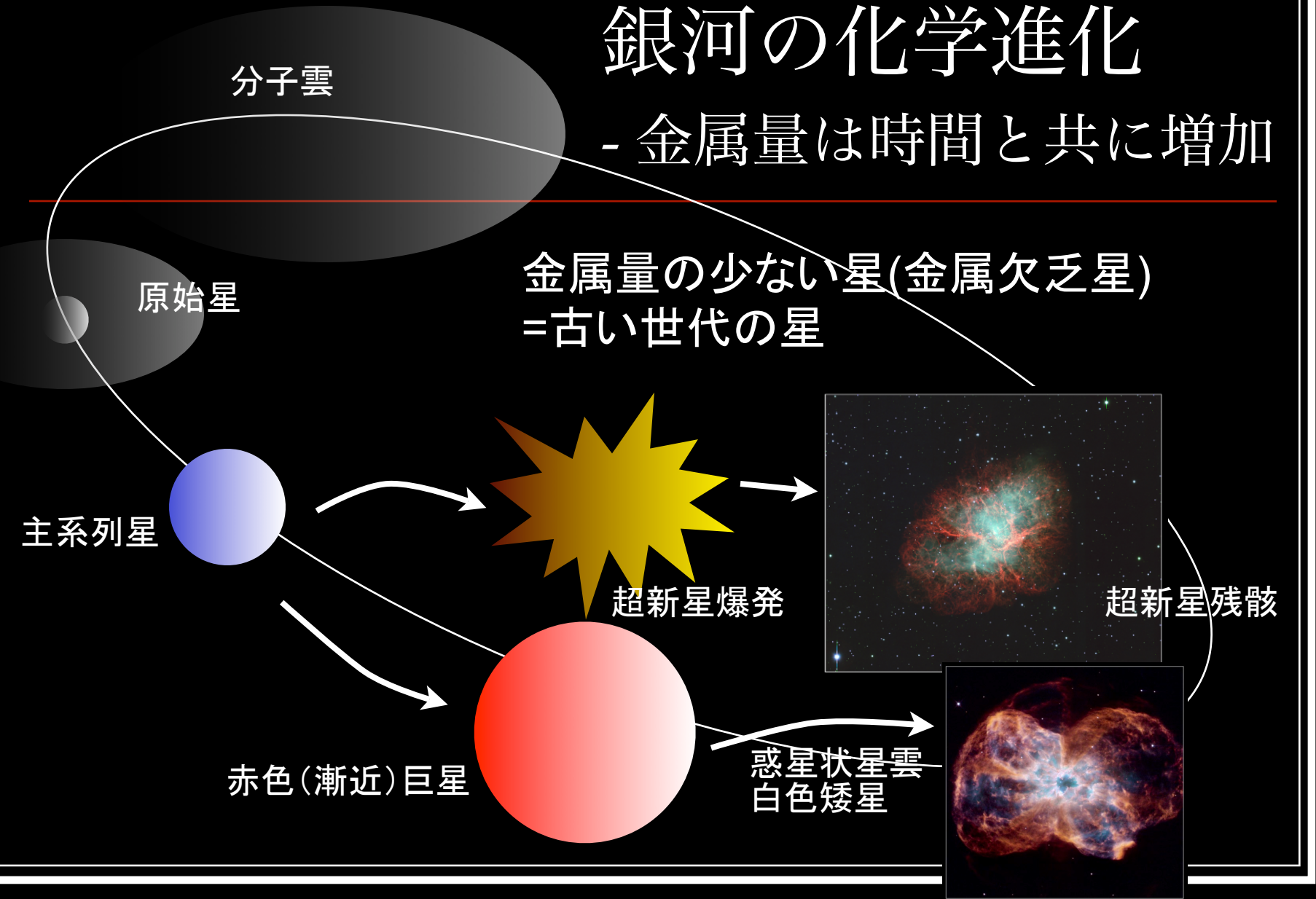
超新星爆発

惑星状星雲
白色矮星

超新星残骸

NGC2440 : from HST

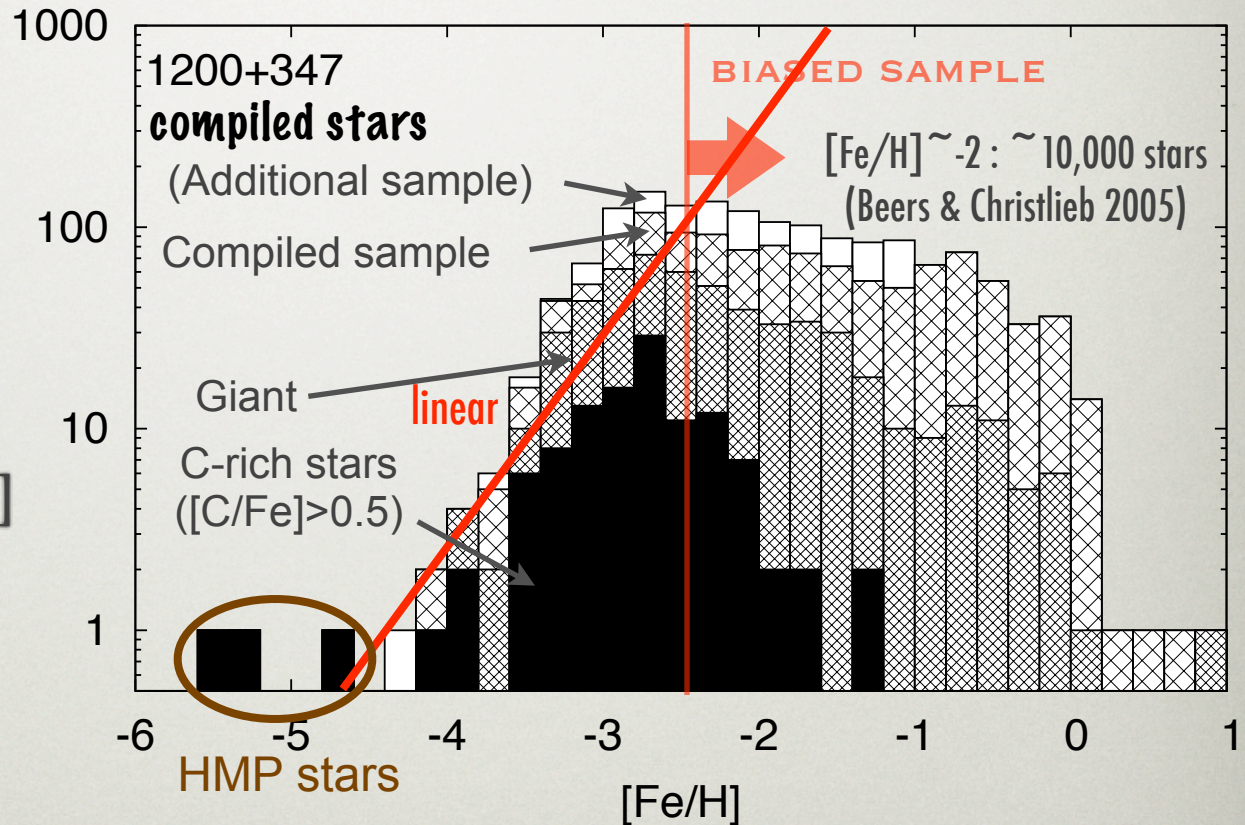
Crab nebula : from Subaru



NUMBER OF OBSERVED EMP STARS - METALLICITY DISTRIBUTION

- Searches for metal-poor stars or Hyper Metal-Poor (HMP) stars in the Galactic halo since 1980s (HK survey, HES survey)
 - HE0107-5240 : -5.3 (Christlieb et al. 2002)
 - HE1327-2026 : -5.4 (Christlieb et al. 2002)
- >100 stars with $[Fe/H] \sim -3$, but 3 stars well below $[Fe/H] = -4$ (Frebel et al. 2005, Aoki et al. 2006)
- HE0557-4840 : -4.8 (Norris et al. 2007)

Histogram of known metal-poor field halo stars



$$[Fe/H] = \log \frac{n_{Fe}}{n_H} - \log \frac{n_{Fe,\odot}}{n_{H,\odot}}$$

Figure created with SAGA -DB
(Suda et al. 2008, PASJ in press)

CHARACTERISTICS OF EMP STARS

- Large fraction of carbon rich stars ($[C/Fe] > \sim 0.5$) (CEMP stars) compared with the Population I & II stars
- Two groups of CEMP stars : with/ without enhancement of s-process elements (CEMP-s and CEMP-no(s), respectively)

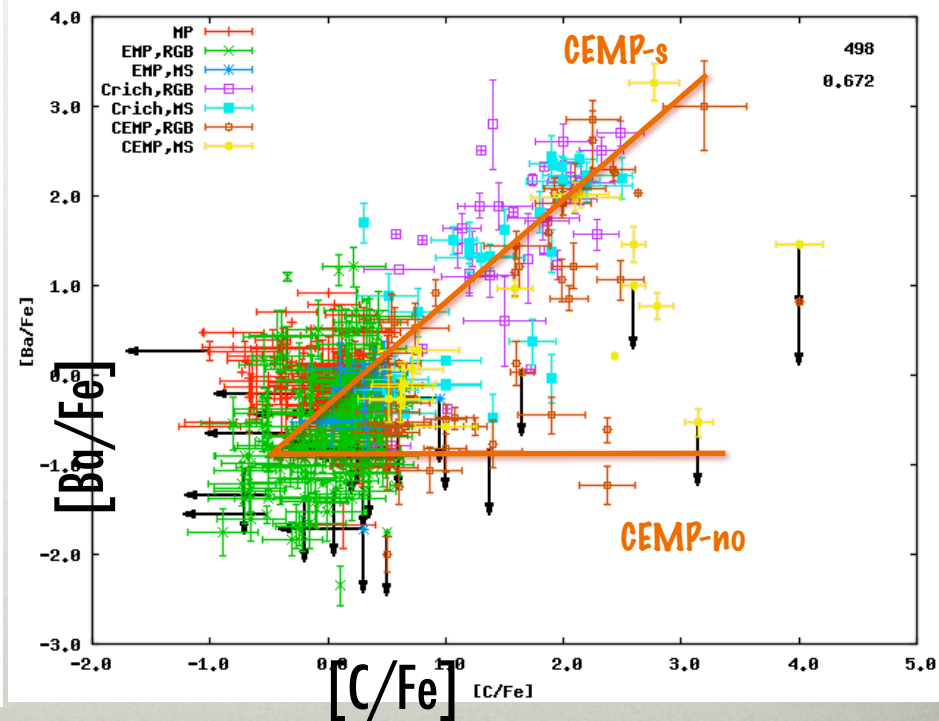
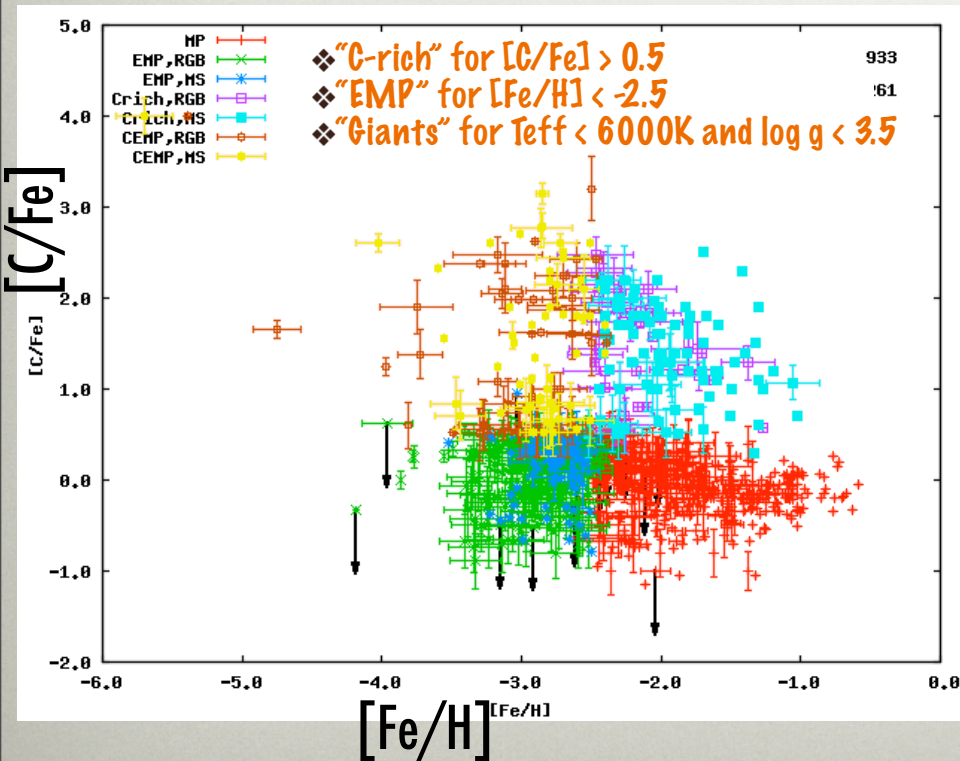


Figure created with SAGA-DB

STATISTICAL TREATMENT OF OBSERVED DATA

THE STELLAR ABUNDANCES FOR GALACTIC ARCHAEOLOGY (SAGA) DATABASE

<http://saga.sci.hokudai.ac.jp/> 2008年6月公開

- 観測データの収集
 - 元素組成解析などを行っている論文のリスト
アップ
- データ入力ツールの開発
 - Webフォームを用いたデータ入力システム
- 収集データの活用
 - 検索システム by Perl CGI + MySQL

DATABASE SAMPLE

- ◆ Papers: 123 (covering since 2000)
- ◆ Stars: 2620(1528)
- ◆ Data
 - ◆ $[X/Fe]$: 15,327
 - ◆ $[X/H]$: 18,015
 - ◆ $\log \epsilon$: 18,015

[Fe/H]	Number
-1<	299
-1~-2	441
-2~-3	644
-3~-4	136
<-4	5

SCREEN SNAPSHOT OF SAGA

Last update of database: 2008-08-07 11:05:02

DATABASE RETRIEVAL SUBSYSTEM

Query

* not working
** Other options do not work

	search	example *	reset
Graph Options			
Axis	Category ▾	any ▾	[Fe/H] From : <input type="text"/> To : <input type="text"/> Include ▾ data with upper limit
Yaxis	Category ▾	any ▾	From : <input type="text"/> To : <input type="text"/> Include ▾ data with upper limit
Criterion +	Category ▾	any ▾	From : <input type="text"/> To : <input type="text"/> Include ▾ data with upper limit
Optional Criterion			
Object	<input type="text"/> ex) "HE0107-5240", "CS", "0107"		
Binarity	<input type="checkbox"/> Binary Nature Period (days) : From <input type="text"/> To <input type="text"/>		
Magnitude	Band ▾ : From <input type="text"/> To <input type="text"/> mag		
Resolution	<input type="text"/> < R < <input type="text"/>		
Bibliographical Criterion			
Author	<input type="text"/> First author ▾ ex) "Lastname" <input checked="" type="radio"/> strict <input type="radio"/> forward agreement <input type="radio"/> backward agreement <input type="radio"/> fuzzy		
Reference	ALL ▾		
Publication Year	From <input type="text"/> To <input type="text"/>		
Retrieval Options			
Display / Page	10 ▾		
Order by**	Object ▾		
Output Option	plot by single file for selected data ▾		
Histogram Option	Bin Width <input type="text"/> Range <input type="text"/> <input type="text"/> (necessary for histogram)		
Cross Search	Retrieve data across papers ▾		
	search	example *	reset

STELLAR EVOLUTION AT [Fe/H] < -3

★ [Fe/H] < ~-2.5 で進化後期
での表面組成が変化する。

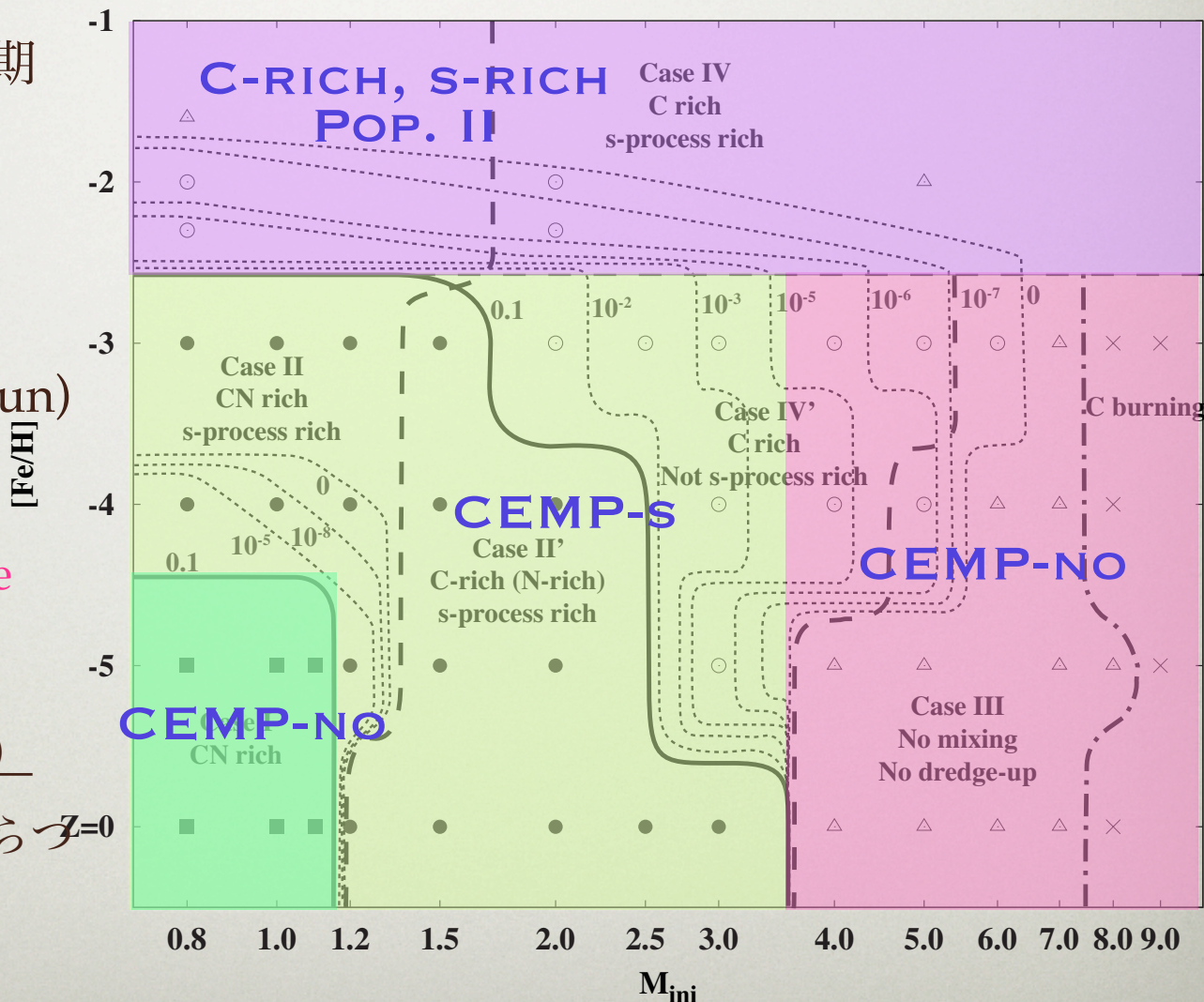
★ C, N rich and/or s-rich
★ AGB と低質量星 (0.8 M_{sun})
との連星系

★ Mass transfer via Roche
lobe overflow or wind
accretion

★ 連星間距離 (連星周期)

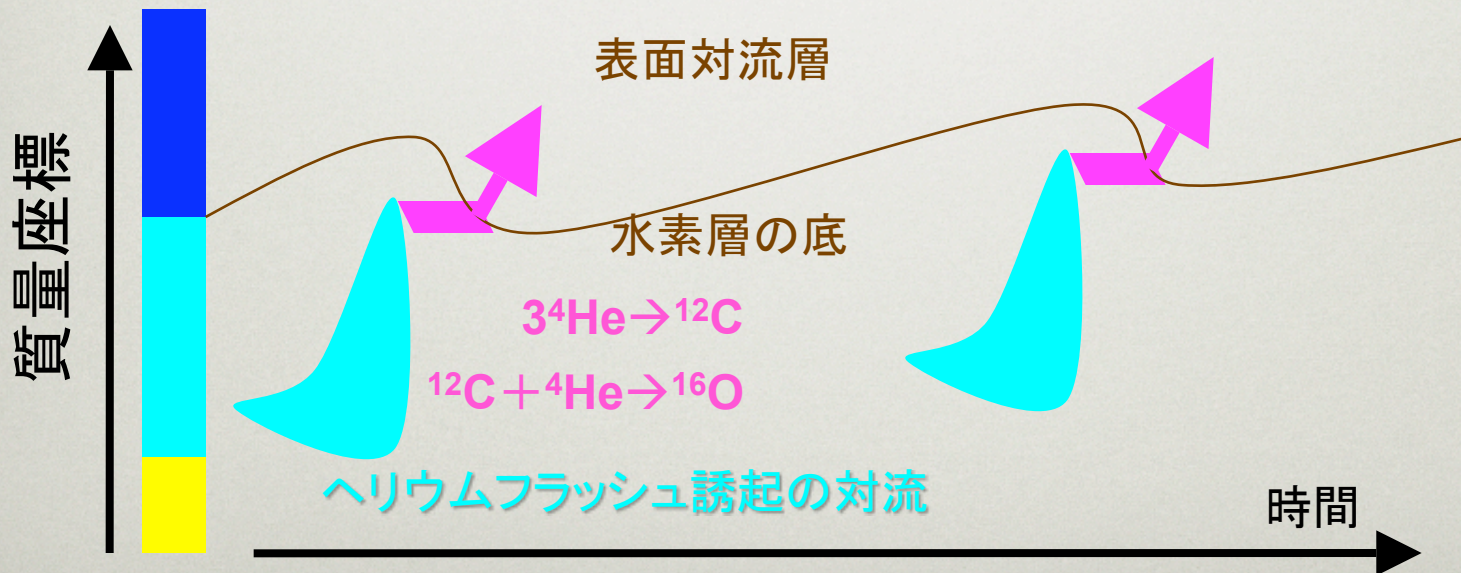
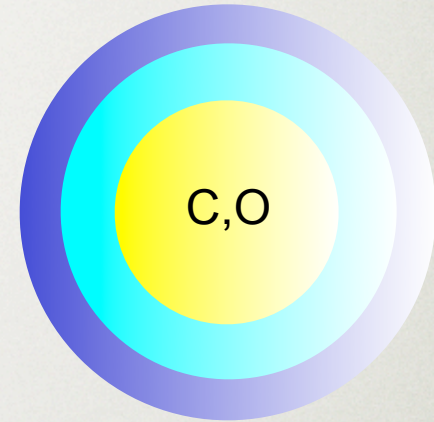
の違いによる組成のばらつき

き



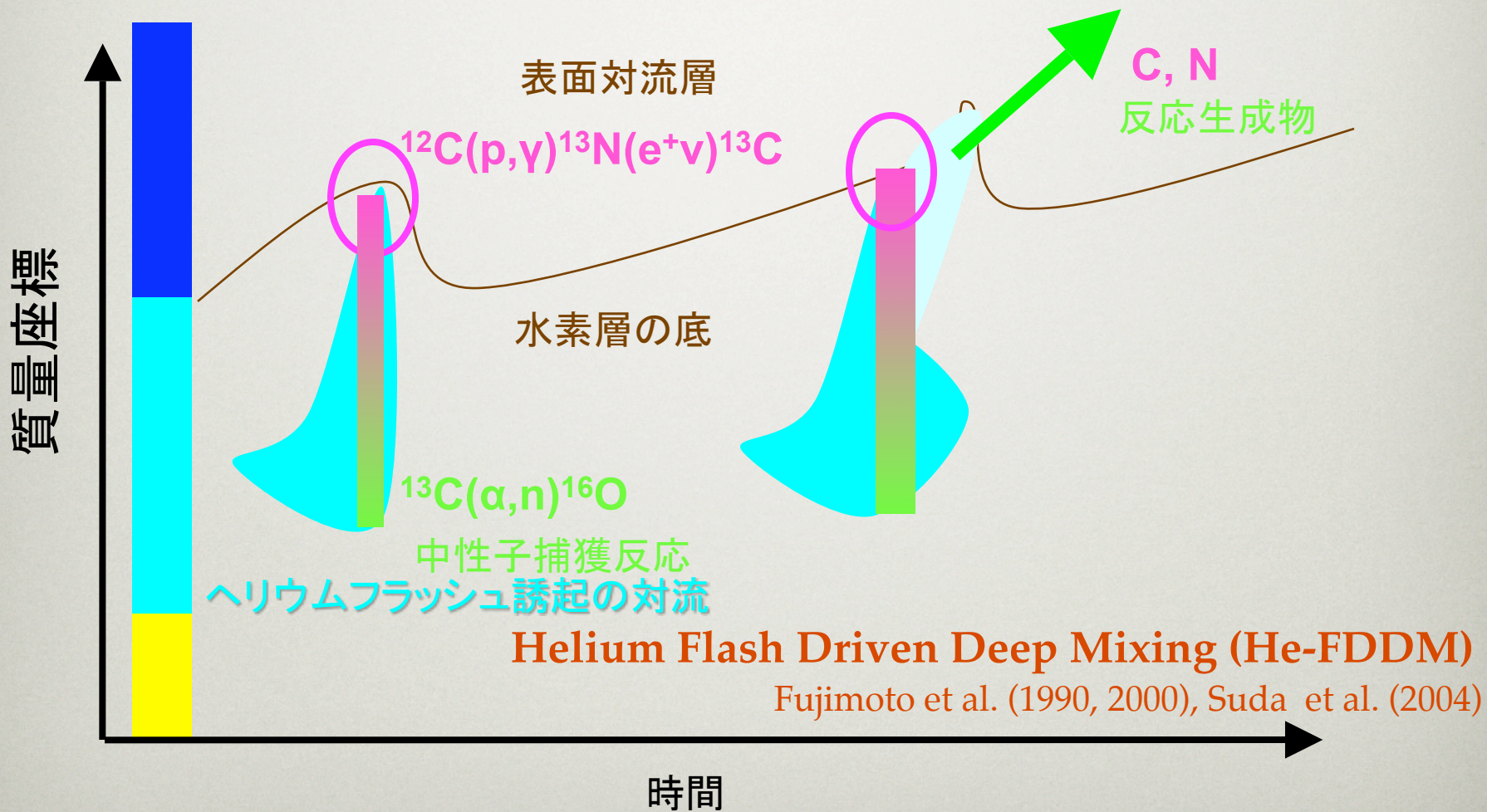
FORMATION OF CARBON STARS - CASE OF POP. I AND II LOW TO INTERMEDIATE MASS STARS

ヘリウム殻燃焼段階でヘリウム殻燃焼で熱パルスが発生，表面へ核生成物(炭素やs-過程元素)が運ばれる。

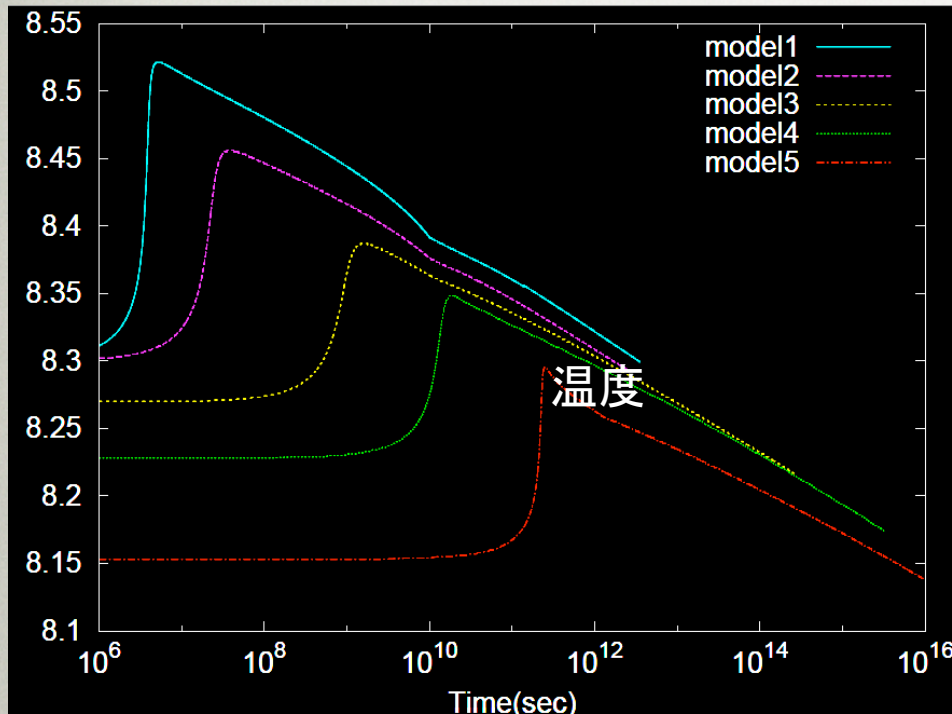


しかし Na, Mg, Al などを説明するのは難しい

FORMATION OF CARBON STARS - CASE OF EMP LOW TO INTERMEDIATE MASS STARS



NUCLEAR NETWORK OF HE-BURNING SHELL



混入継続時間(τ_{mix})

•Mixing Parameters

• ^{13}C 混入量= $^{13}\text{C}/^{12}\text{C}$

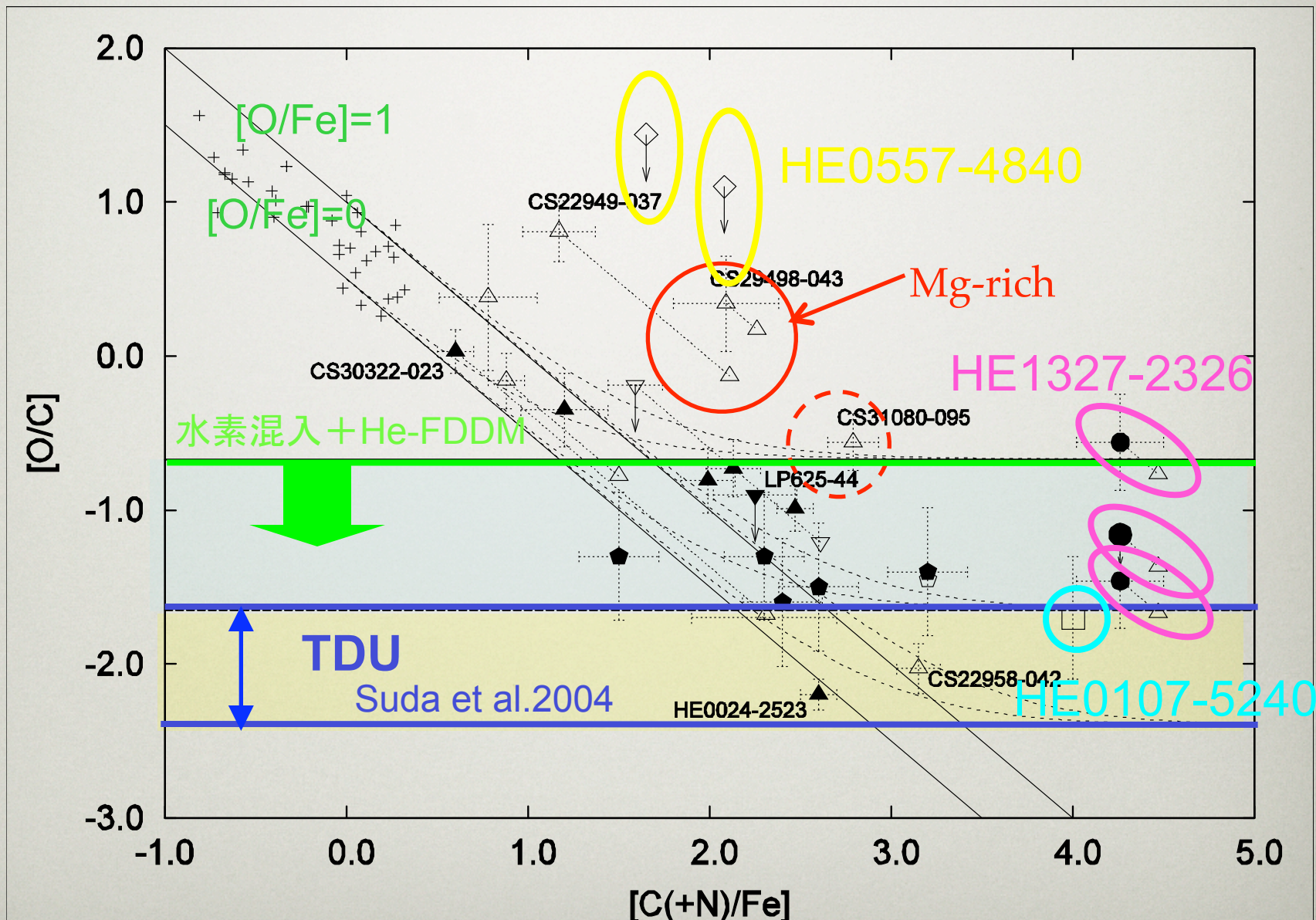
•混入継続時間= τ_{mix}

•領域を平均化 **one-zone model**

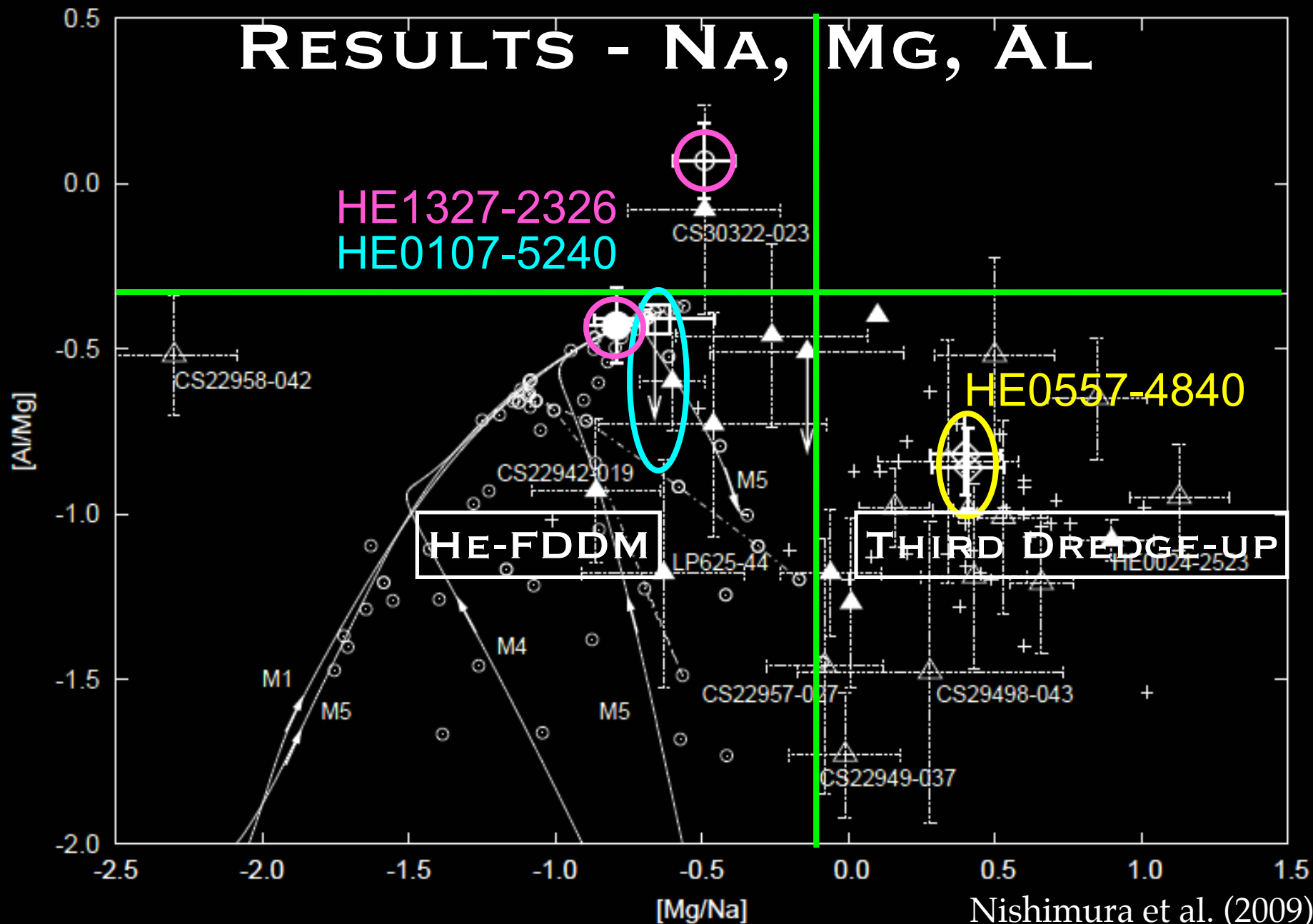
•He burning 層が薄い

•thin shell approximation (Fujimoto & Sugimoto 1979)

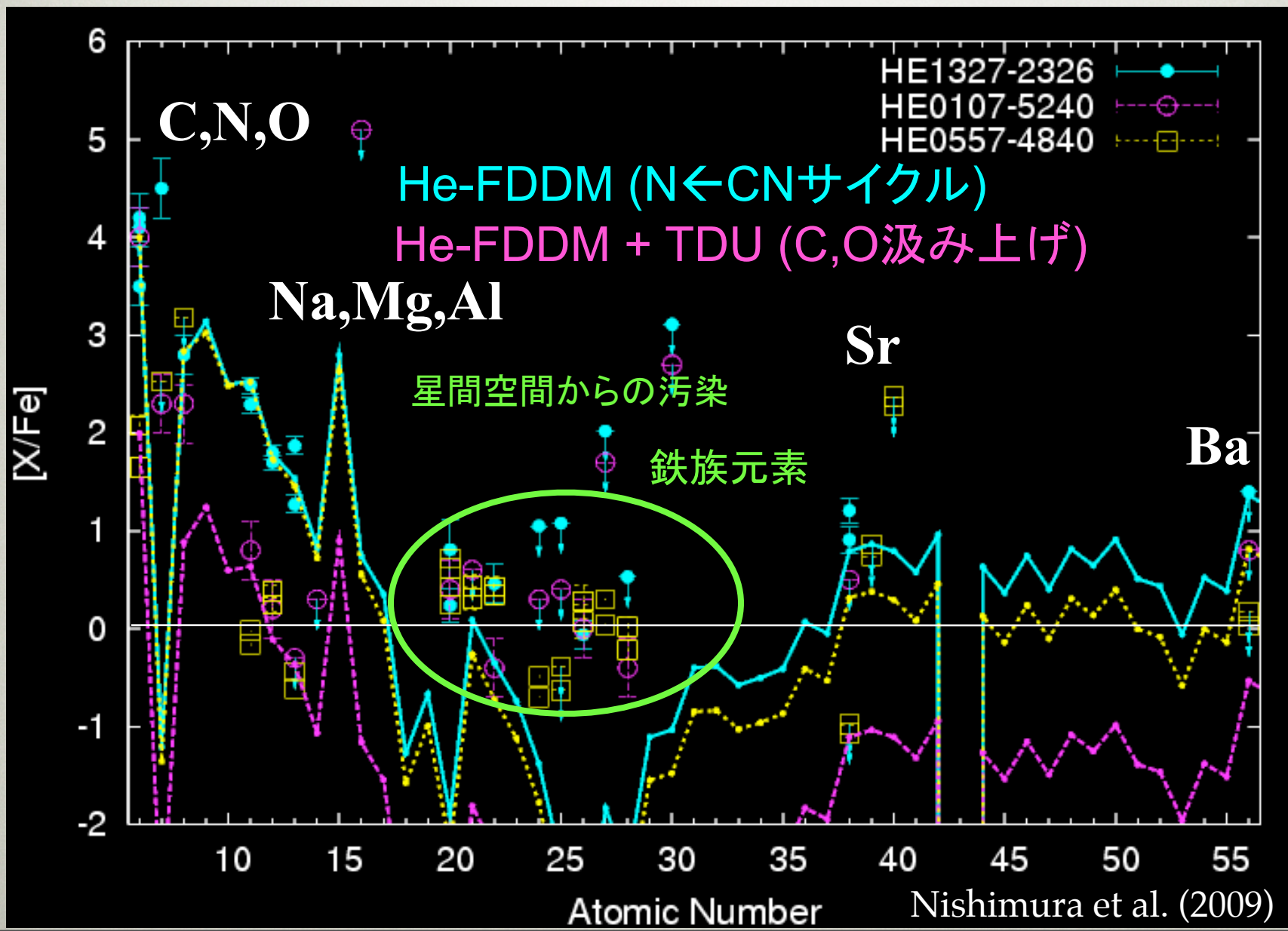
RESULTS - CNO ELEMENTS



RESULTS - NA, MG, AL



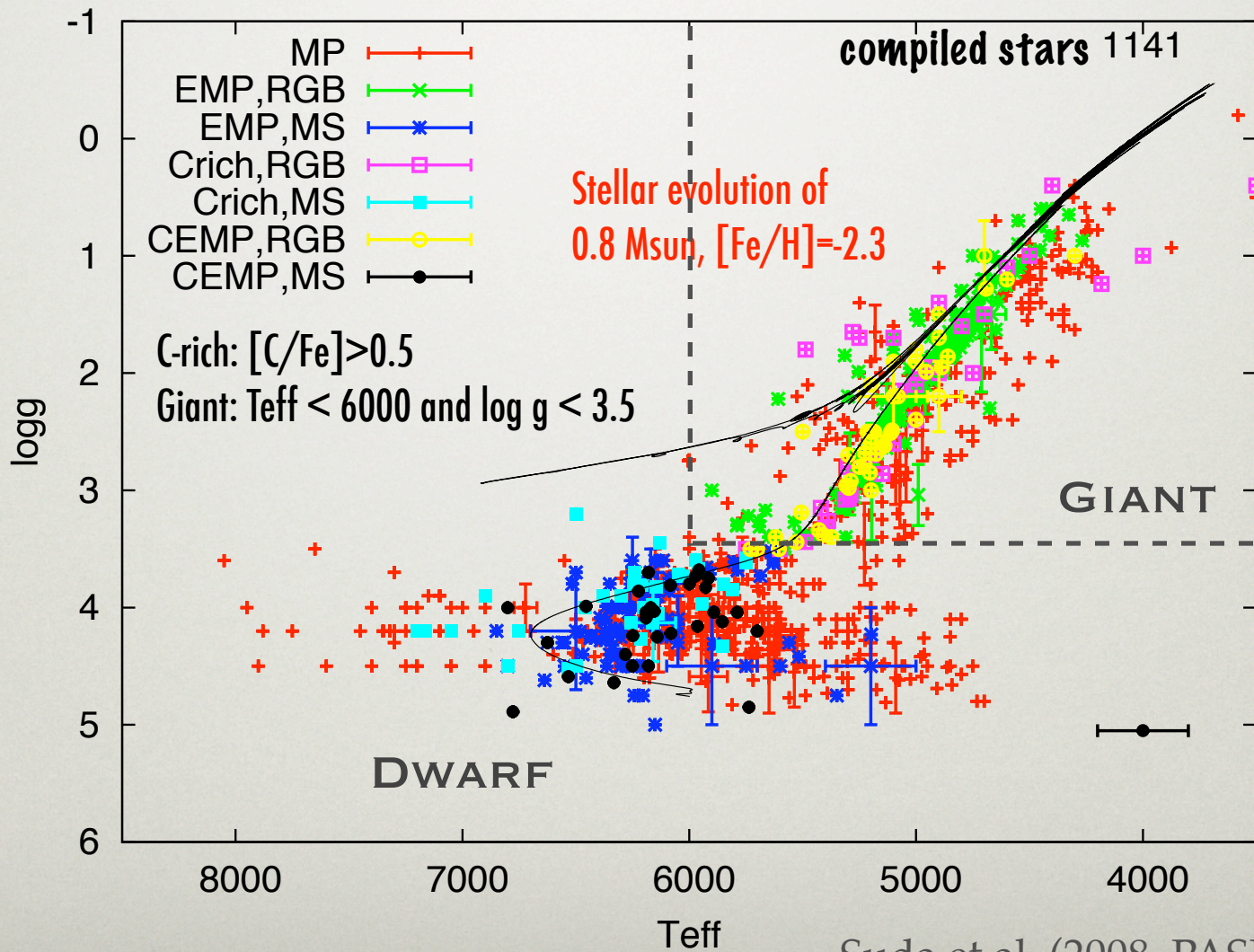
COMPARISONS OF ABUNDANCE PATTERN WITH HMP STARS



ORIGINS OF MOST IRON-POOR STARS

- HE1327-2326 ($M_p < 1.5 M_{\text{sun}}$)
 - He-FDDM (CNO, NaMgAl)
- HE0107-5240
 - He-FDDM + TDU ($1.5 < M_p / M_{\text{sun}} < 3$)
 - C, O from TDU
 - NaMgAl from He-FDDM
- HE0557-4840 ($3 M_{\text{sun}} < M_p$)
 - TDU only

SAGA SAMPLE STARS ON H-R DIAGRAM



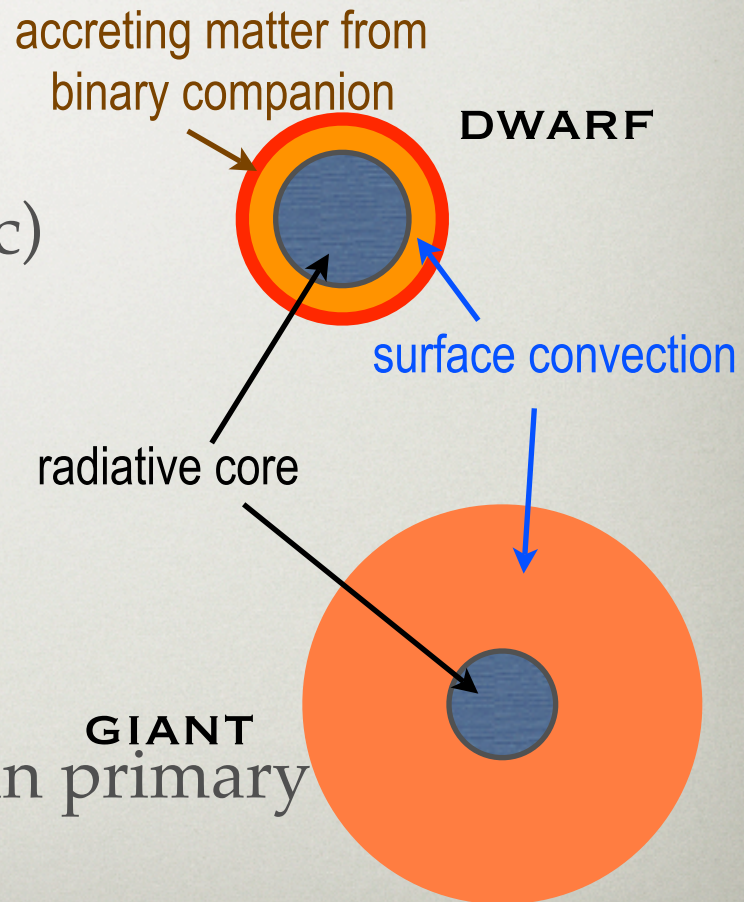
DILUTION EFFECT IN BINARY HYPOTHESIS

Effect of dilution by the surface convection of
0.8 Msun stars assuming:

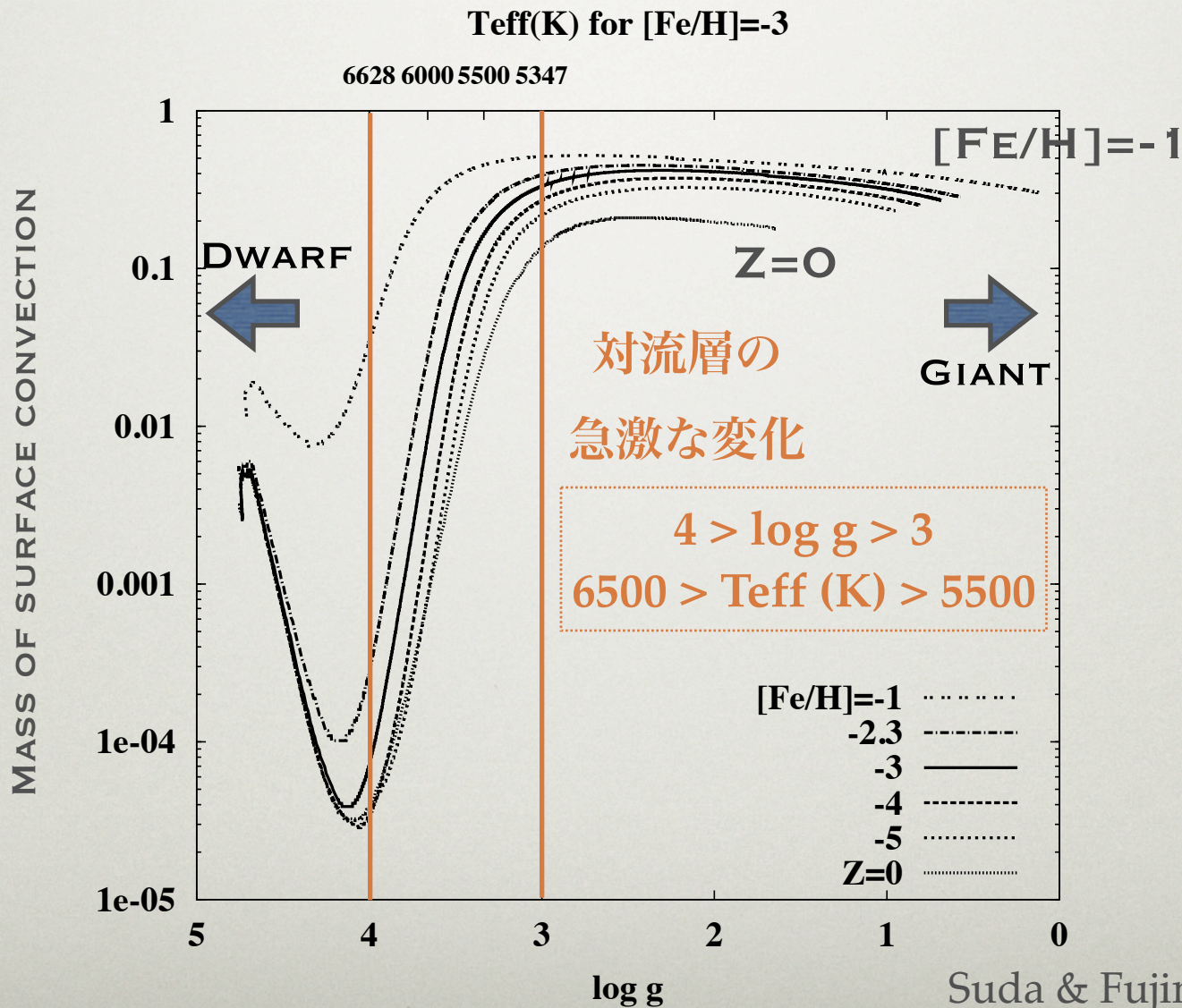
- ★ $[C/Fe]_{ini} = 0.0$
- ★ Static accretion at $t = 2 \times 10^{16}$ (sec)
 - ★ AGB evolution of 2 Msun

Parameters

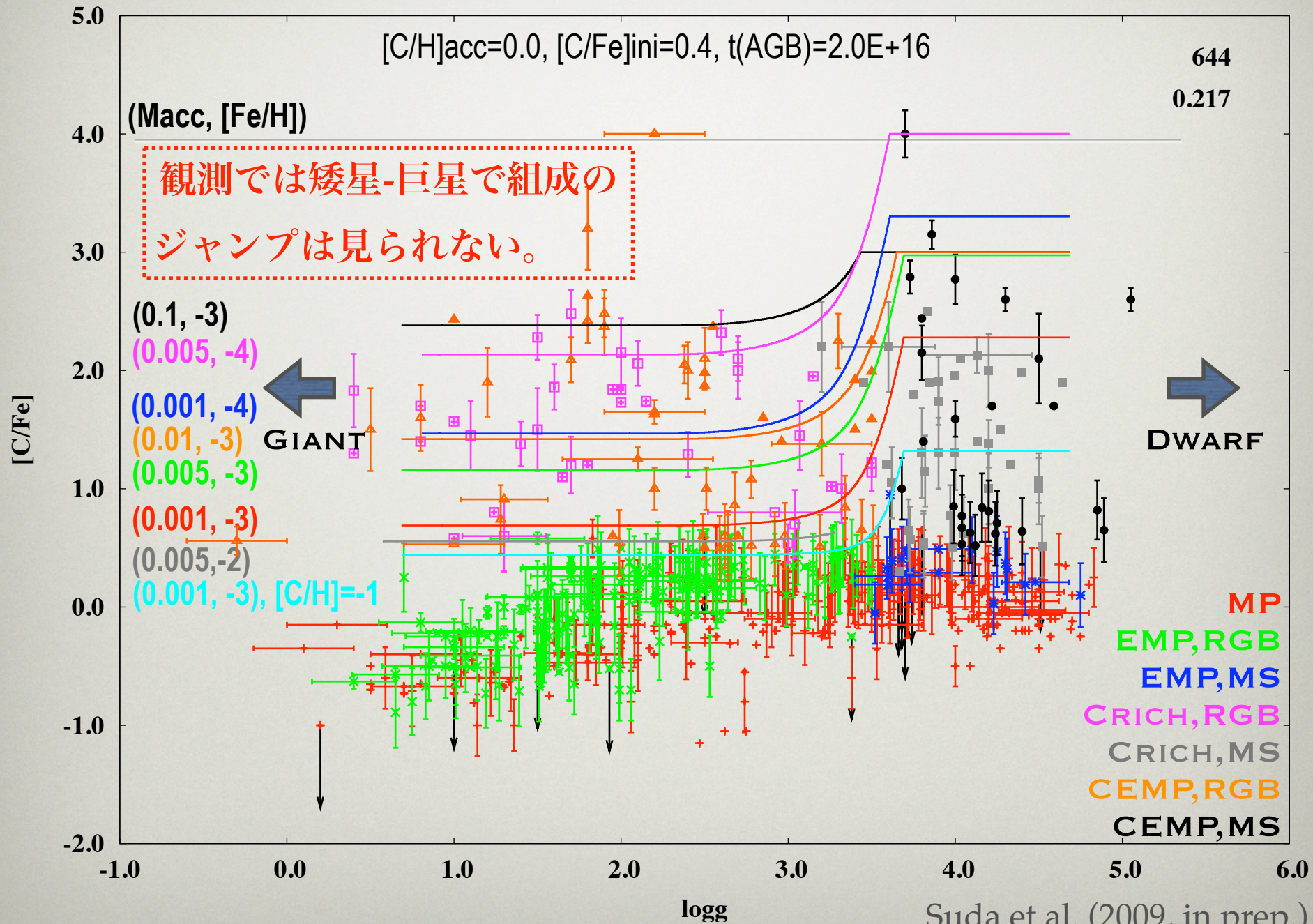
- ★ M_{acc} : accreting mass
- ★ $[Fe/H]$: metallicity
- ★ $[X/H]_{acc} = -1.0 - 0.0$
 - ★ enhancement of element X in primary



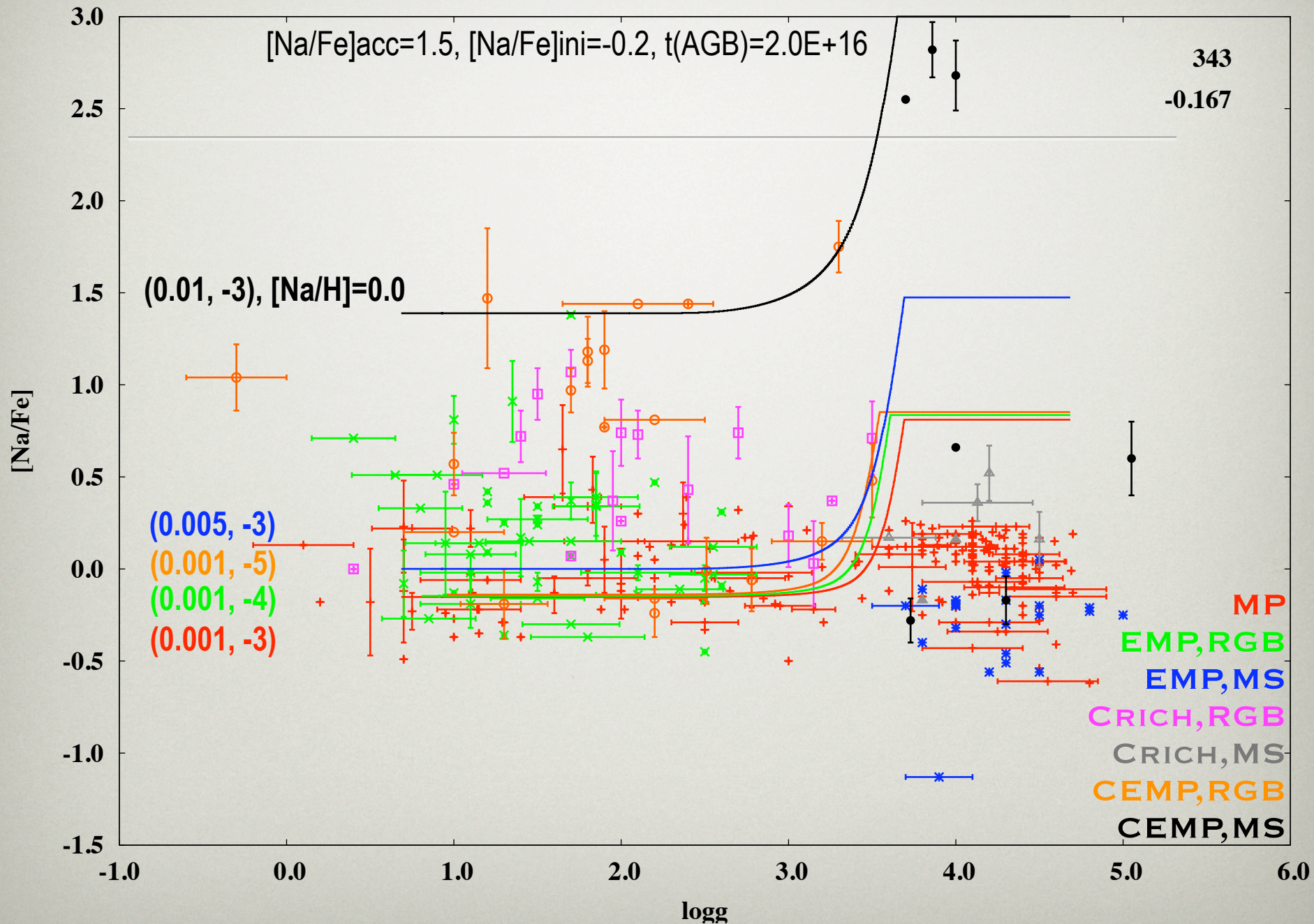
DILUTION EFFECT BY SURFACE CONVECTION



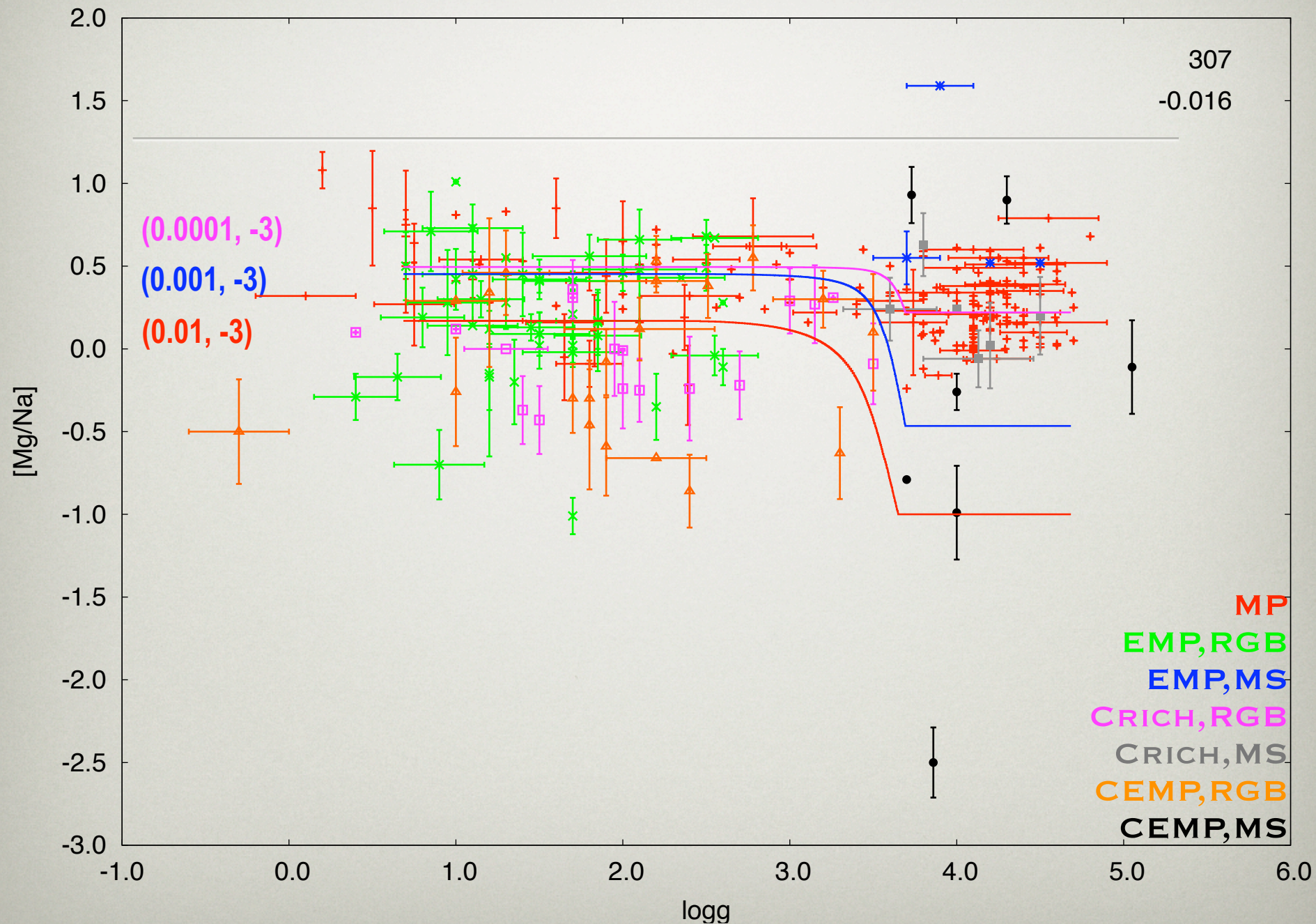
DILUTION EFFECT - CASE OF CARBON



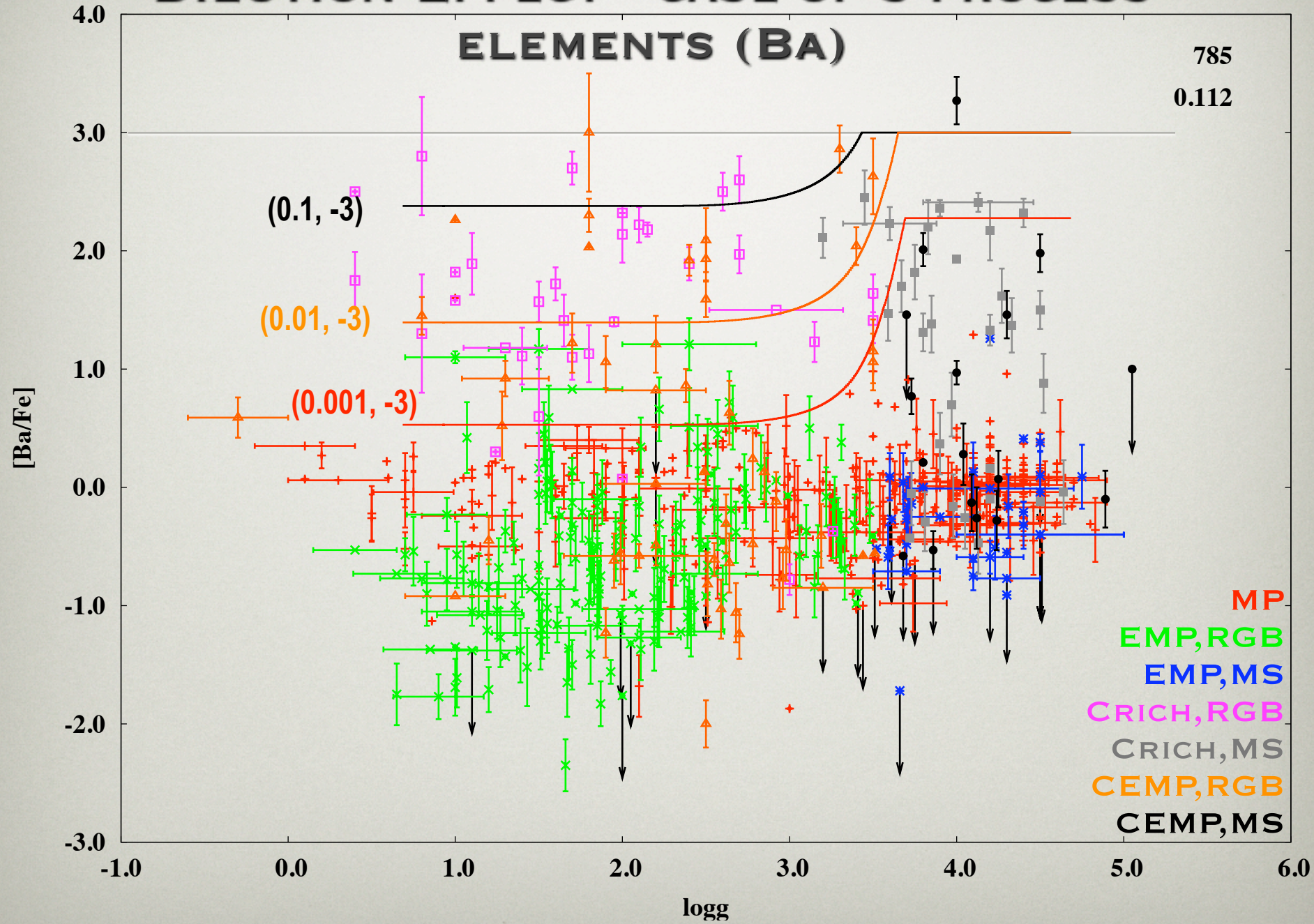
DILUTION EFFECT - CASE OF SODIUM



DILUTION EFFECT - CASE OF [Mg/Na]



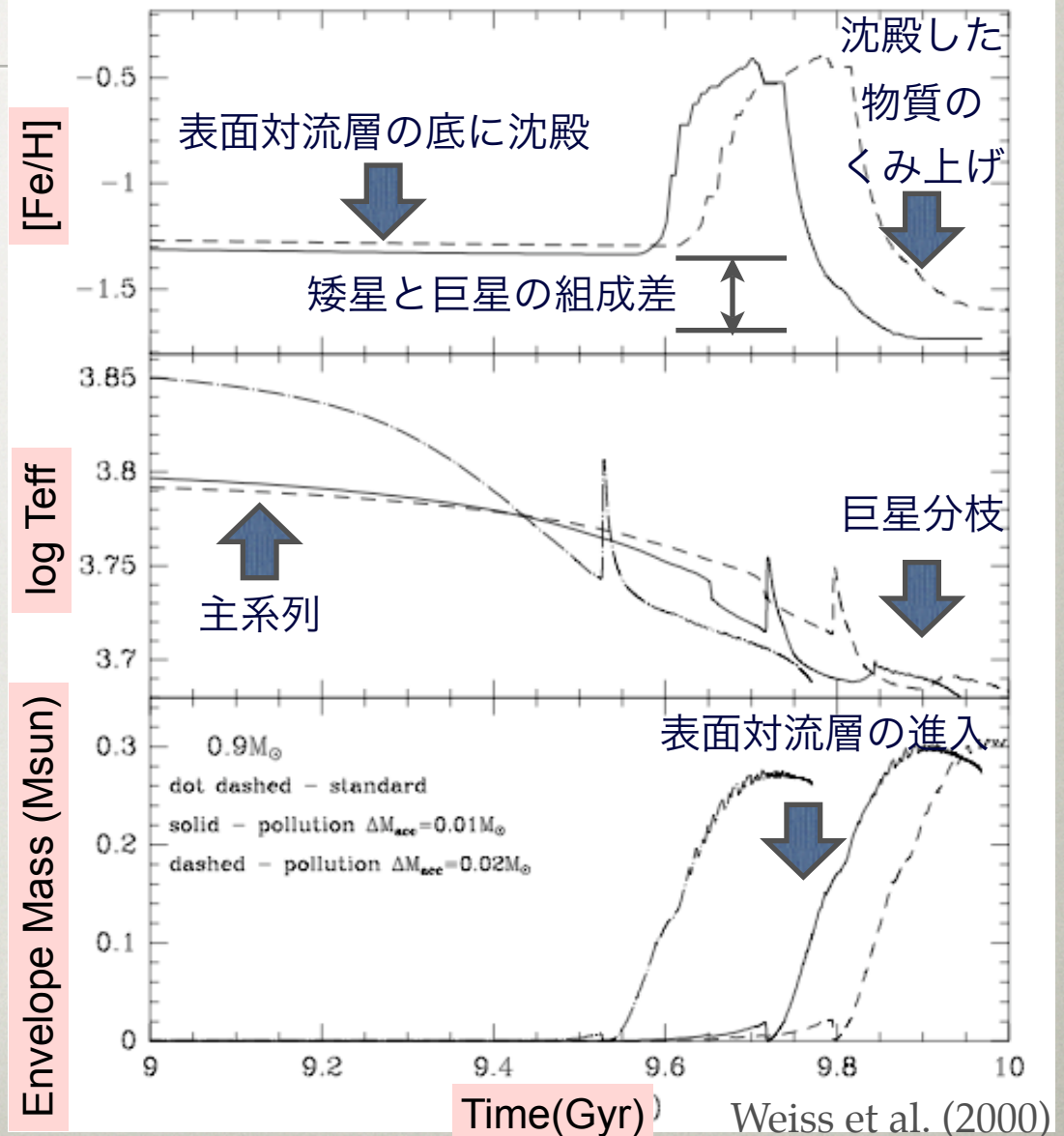
DILUTION EFFECT - CASE OF S-PROCESS ELEMENTS (BA)



DIFFUSION DURING MAIN SEQUENCE

- Inclusion of diffusion during the MS phase.
 - pressure (gravity) diffusion, thermal diffusion, and ion-electron interactions
 - now in progress (applied to white dwarf)
- 表面对流層の底に沈殿した物質が巨星へと進化する際に表面にくみ上げられる。

Effect of external pollution - $Z=0.01$ のmatterを
0.01 M_{sun} だけ $Z=0$, 0.8 M_{sun} モデルに降着



MASSIVE EMP BINARIES (1)

- Komiya et al. (2007, 2009)によると現在観測されているEMP starsはほとんどがbinary companion
 - 観測されるCEMP-s, CEMP-nosの比
 - 銀河系のFeの化学進化
- IMFのpeakは $\sim 10 M_{\text{sun}}$
 - binaryのmass ratio依存性はそれほど大きくない。

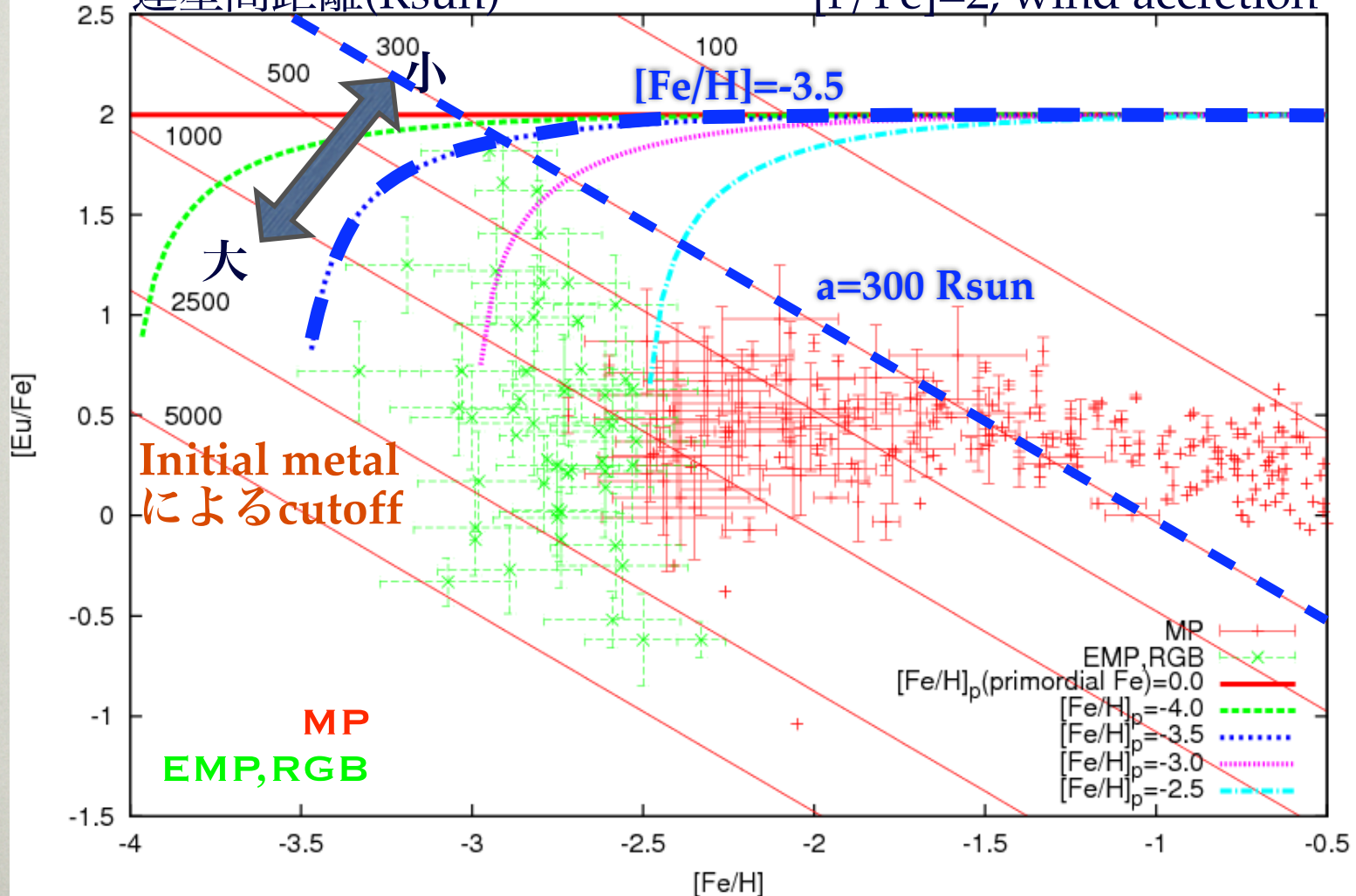
Massive star + low-mass starの連星の証拠があるはず

MASSIVE EMP BINARIES (2)

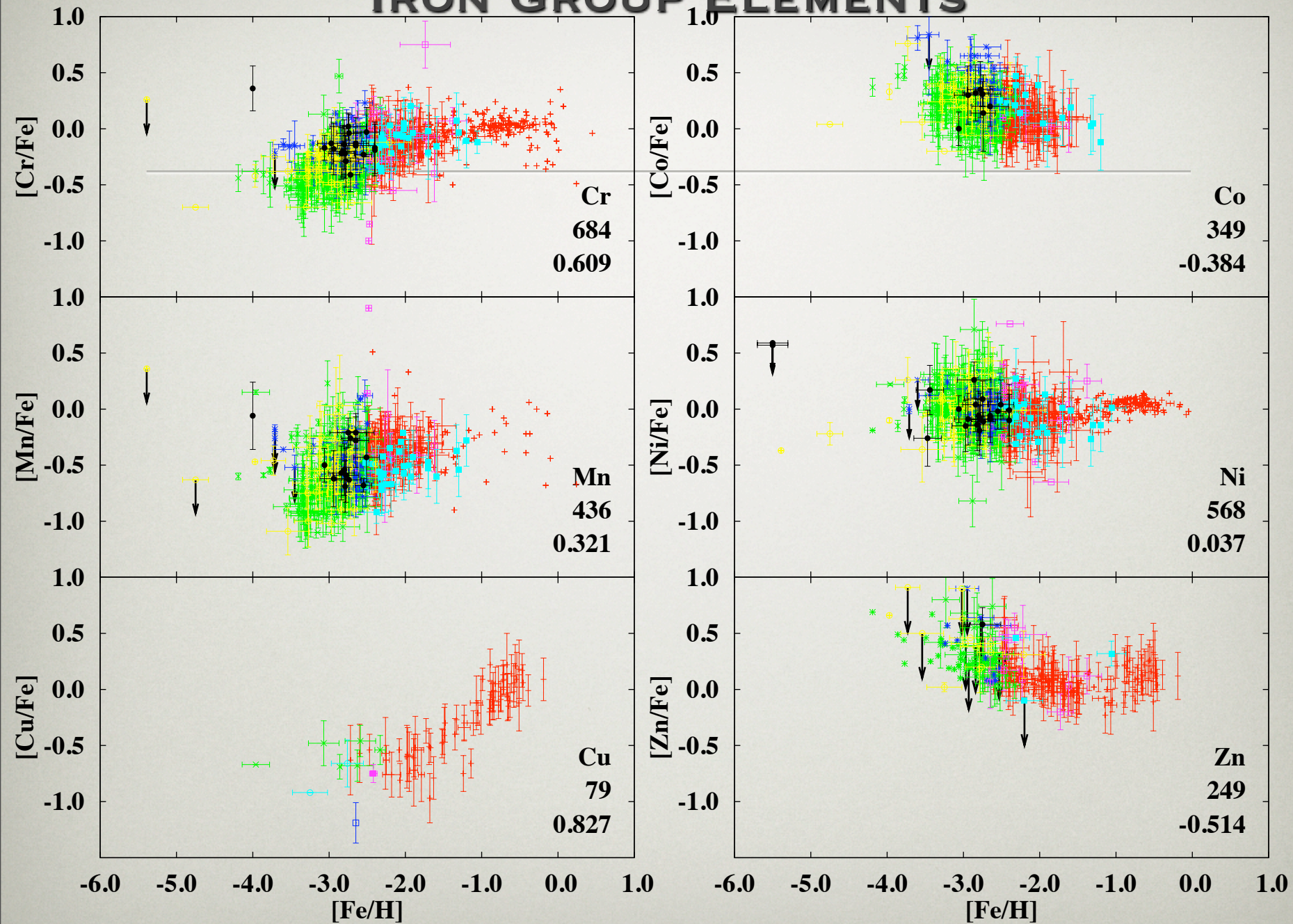
Primary: ~10 Msun, Secondary: 0.8 Msun giant

連星間距離(Rsun)

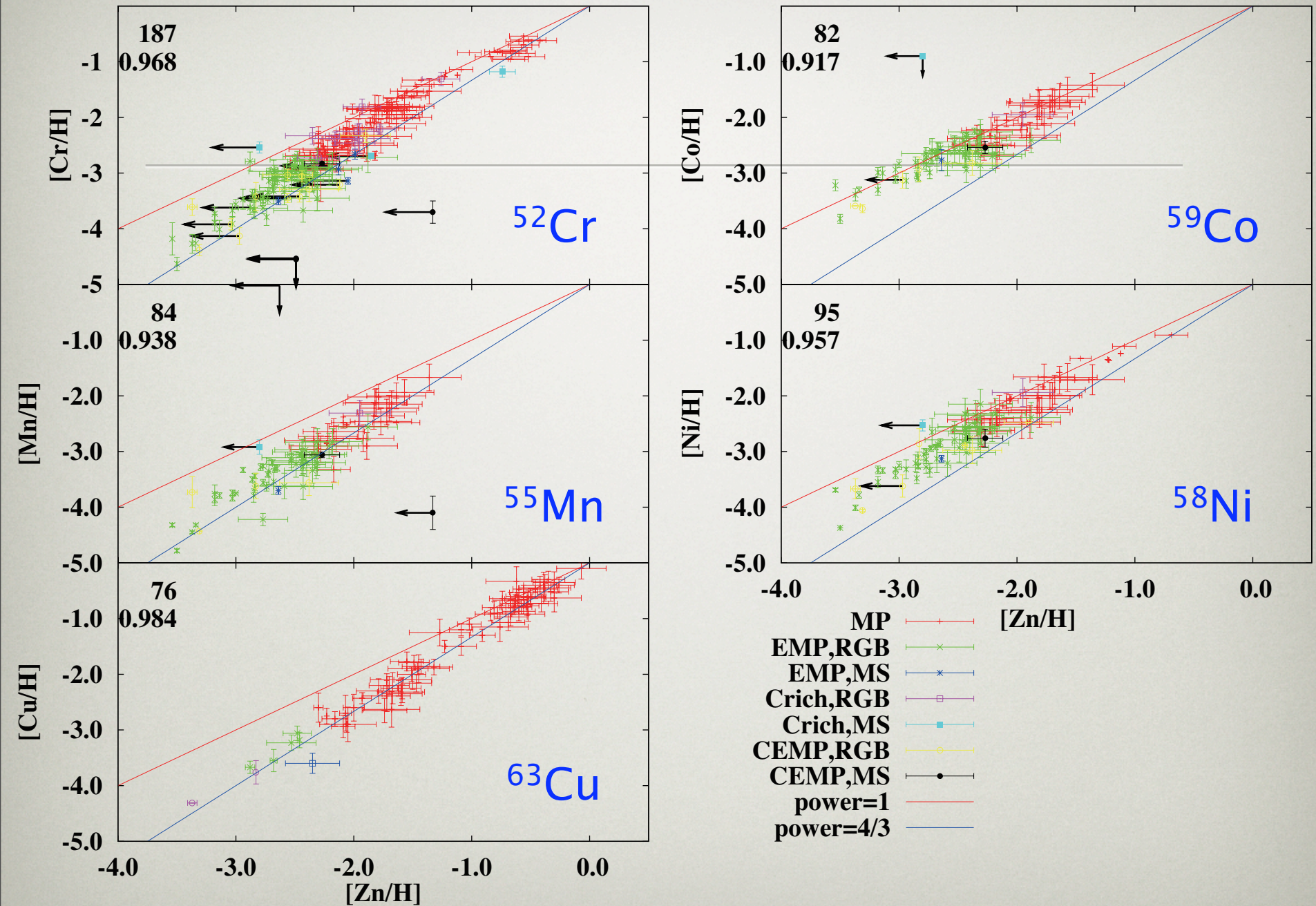
$[r/Fe]=2$, wind accretion



IRON GROUP ELEMENTS



IRON GROUP VS. ZINC



CONCLUSIONS

- He-Flash Driven Deep Mixing元素合成モデルと金属欠乏星の観測データを比較した。
 - C/O, Mg/Na, Al/Mg比で元素合成の起源を分類可能。
 - HMP星の起源を連星シナリオで統一的に解釈できる。
- 連星起源の観測的証拠をSAGA databaseで調べた。
 - 表面对流による希釈効果は直接的には見られない。
 - すべてbinary起源とされるCEMP-sでも見られない。
 - 主系列における重力拡散（あるいは熱拡散）が働いているかもしれない。
 - r-process起源の元素がMassive star binariesで説明可能。
 - 鉄族元素の一部とZn組成が $4/3$ 乗の冪に乗る。