ABUNDANCES OF MASSIVE STARS
SOME RECENT DEVELOPMENTS

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Chemical composition of nearby OB stars: solar?

- **Modelling of pulsations and inferences on internal structure**
- **Constraints on Galactic chemical evolution models**

Deep mixing in OB stars

- **Theoretical understanding of mixing processes**
- **Impact on evolution off the main sequence**

Getting the abundances

Atmospheric parameters

Teff: photometry/ionization balance
logg: fitting wings of Balmer lines
microturbulence: no dependence between metal abundances and EWs

Model atmospheres and line-formation codes

Line-blanketed model atmospheres (LTE or NLTE)

NLTE line-formation treatment

- **Stars with winds: unified codes (CMFGEN, FASTWIND)**
- **Stars without winds: plane-parallel codes (TLUSTY, DETAIL/SURFACE)**

Atomic data

Model atom
Oscillator strengths, ...

Techniques for abundance determination

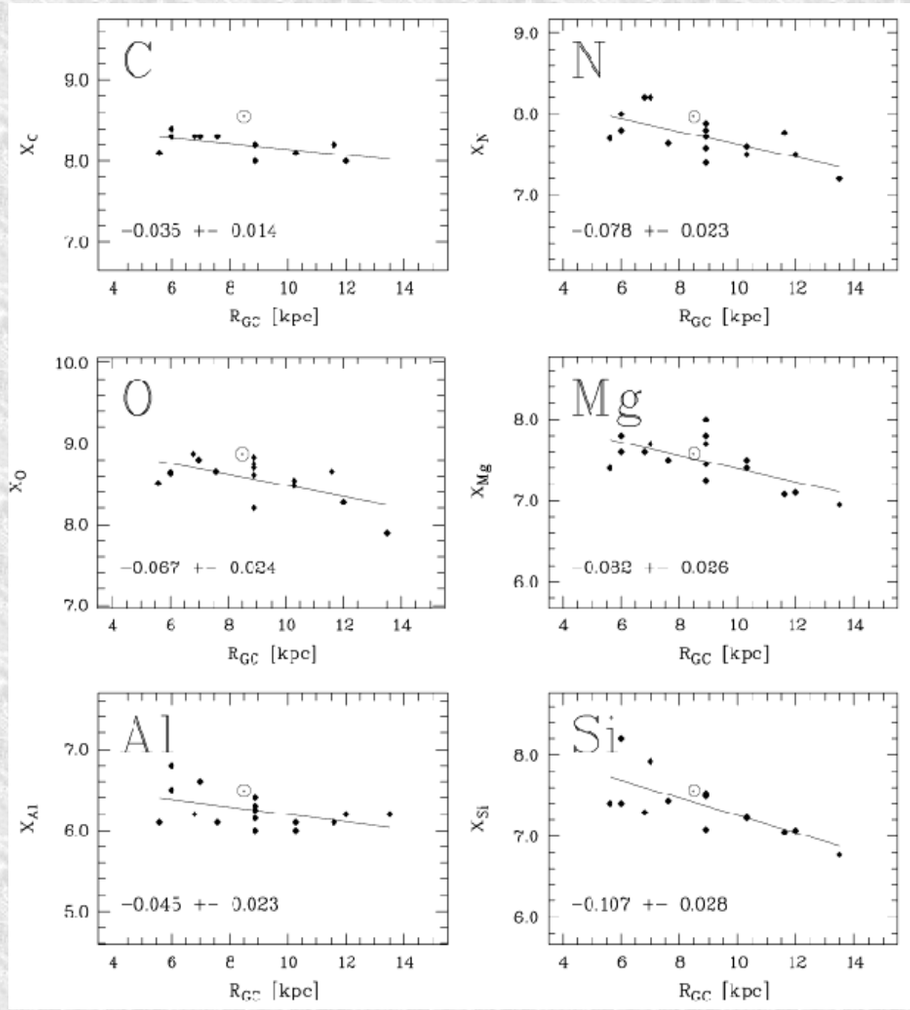
Curve of growth/spectral synthesis

Chemical composition of nearby OB stars: the data

Selection criteria:

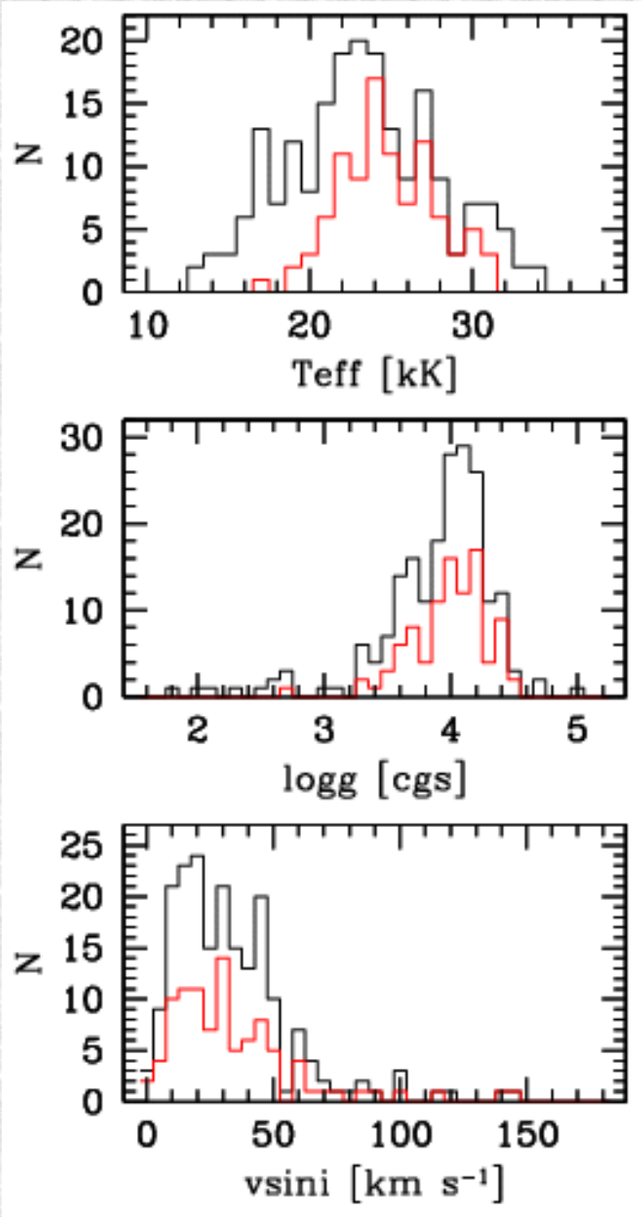
- Only single stars
- No supergiants to minimize evolutionary effects
- Only stars within ~1 kpc
- Only NLTE studies using line-blanketed model atmospheres
- Only studies based on high-resolution optical spectra
- Carbon abundances solely based on 'problematic' lines excluded (e.g. C II 4267)

Data from ~10 studies: heterogeneous, BUT general trends emerging



Gummersbach et al. (1998)

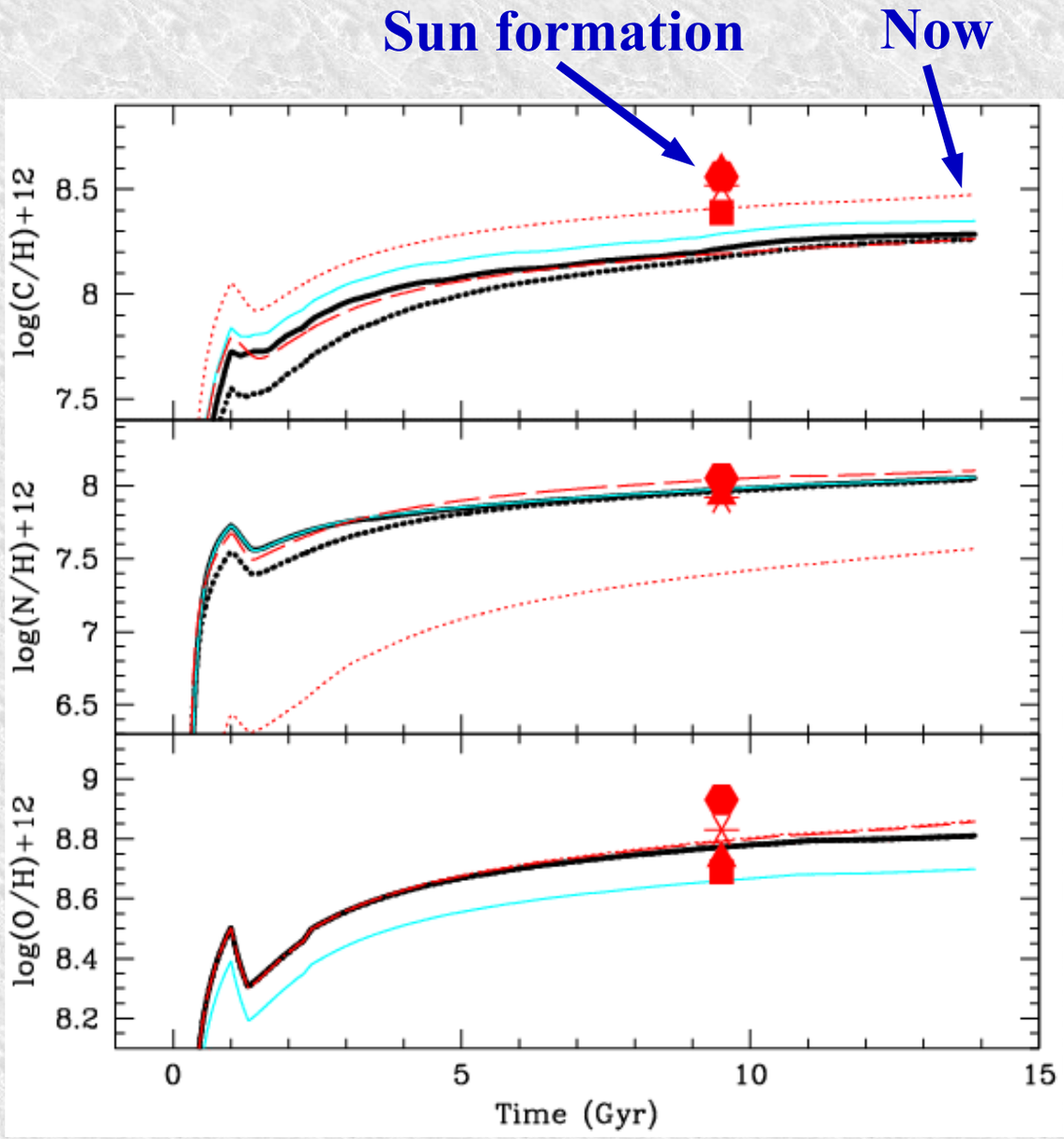
Chemical composition of nearby OB stars: the data



Stars with abundance data (CNO, Mg, Al, Si, S or Fe)
~200 objects

Stars with CNO data
~100 objects

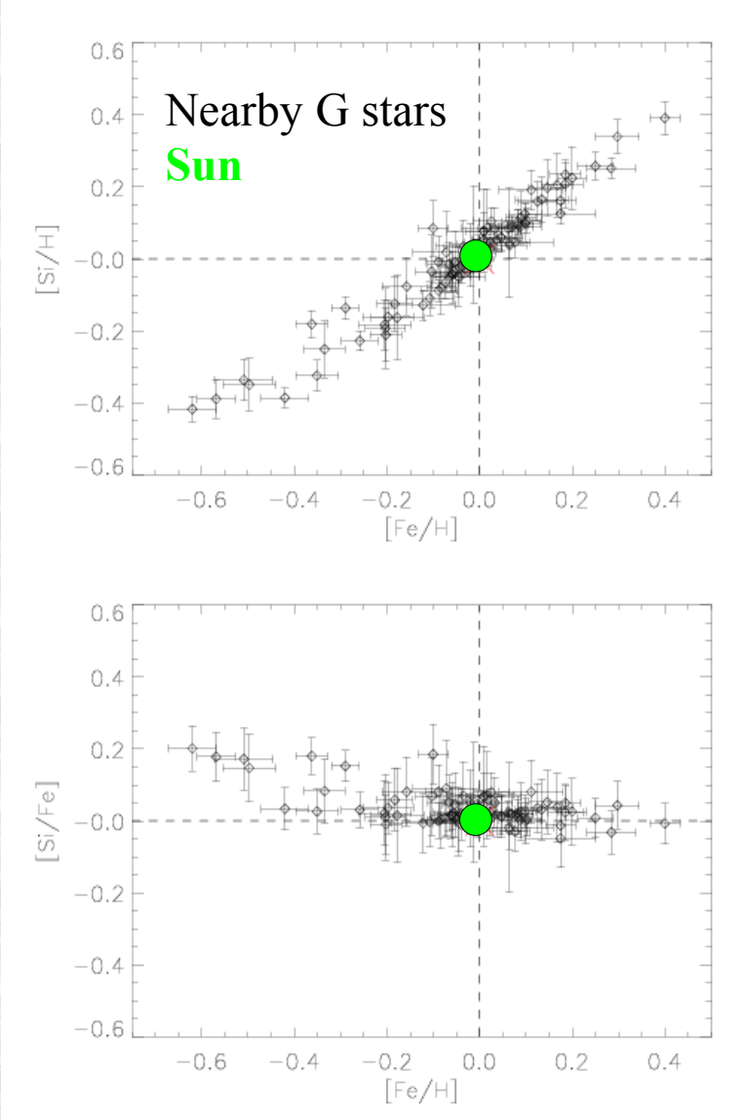
Chemical composition of nearby OB stars: Galactic enrichment

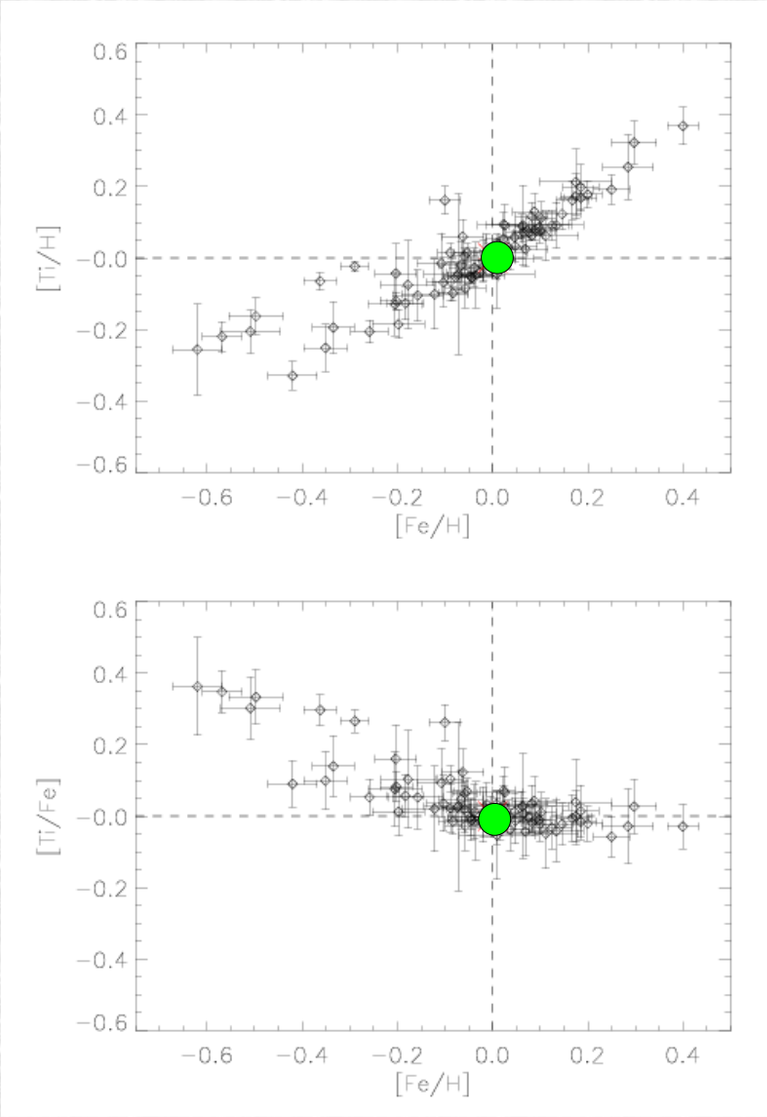


Element	Enrichment since Sun formation (dex)
C	0.07
N	0.10
O	0.05
Fe	0.16
Ne	0.04
S	0.10
Si	0.08
Mg	0.04

Chiappini et al. (2003)

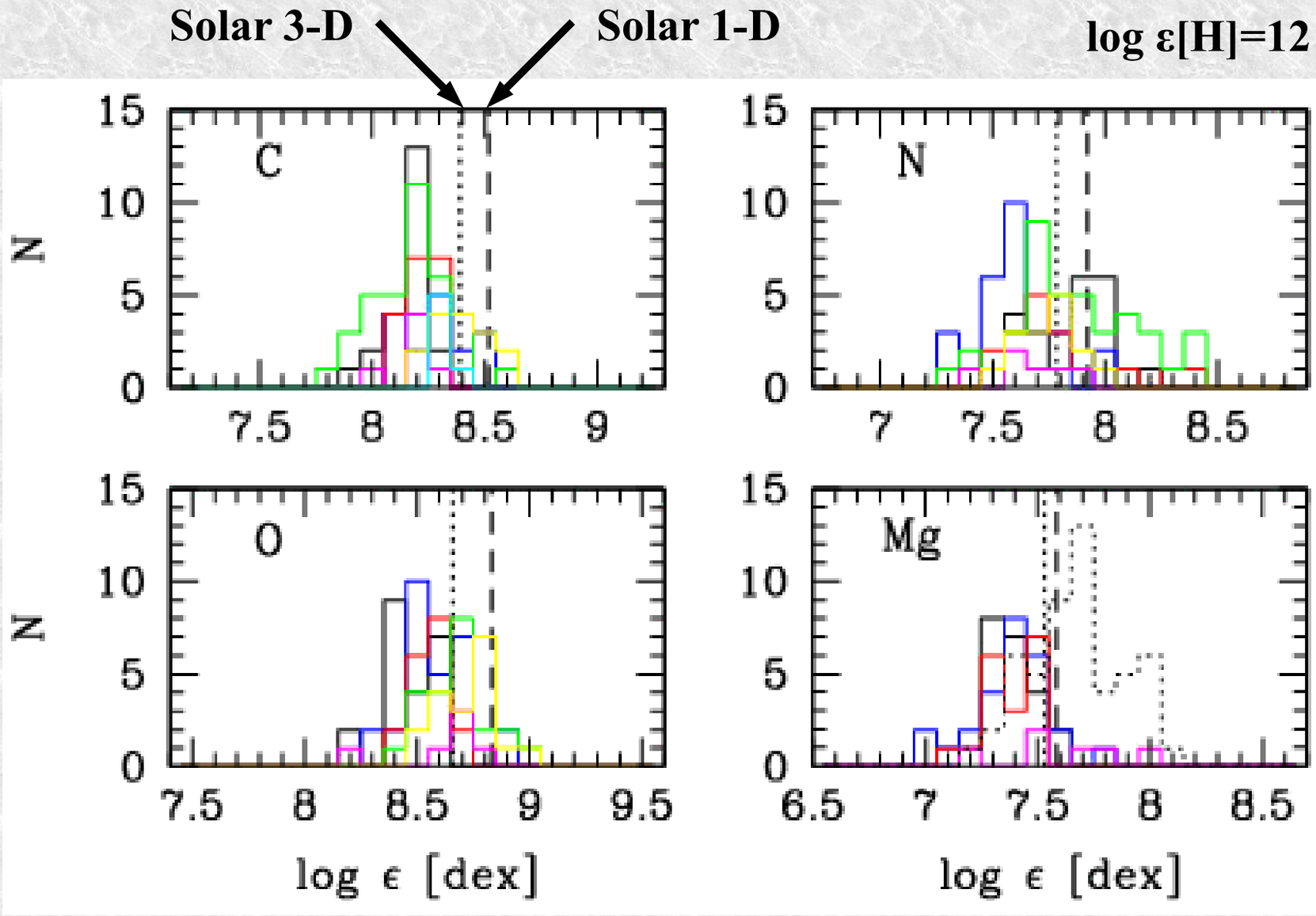
Chemical composition of nearby OB stars: the Sun is 'normal'





Allende-Prieto (2006)

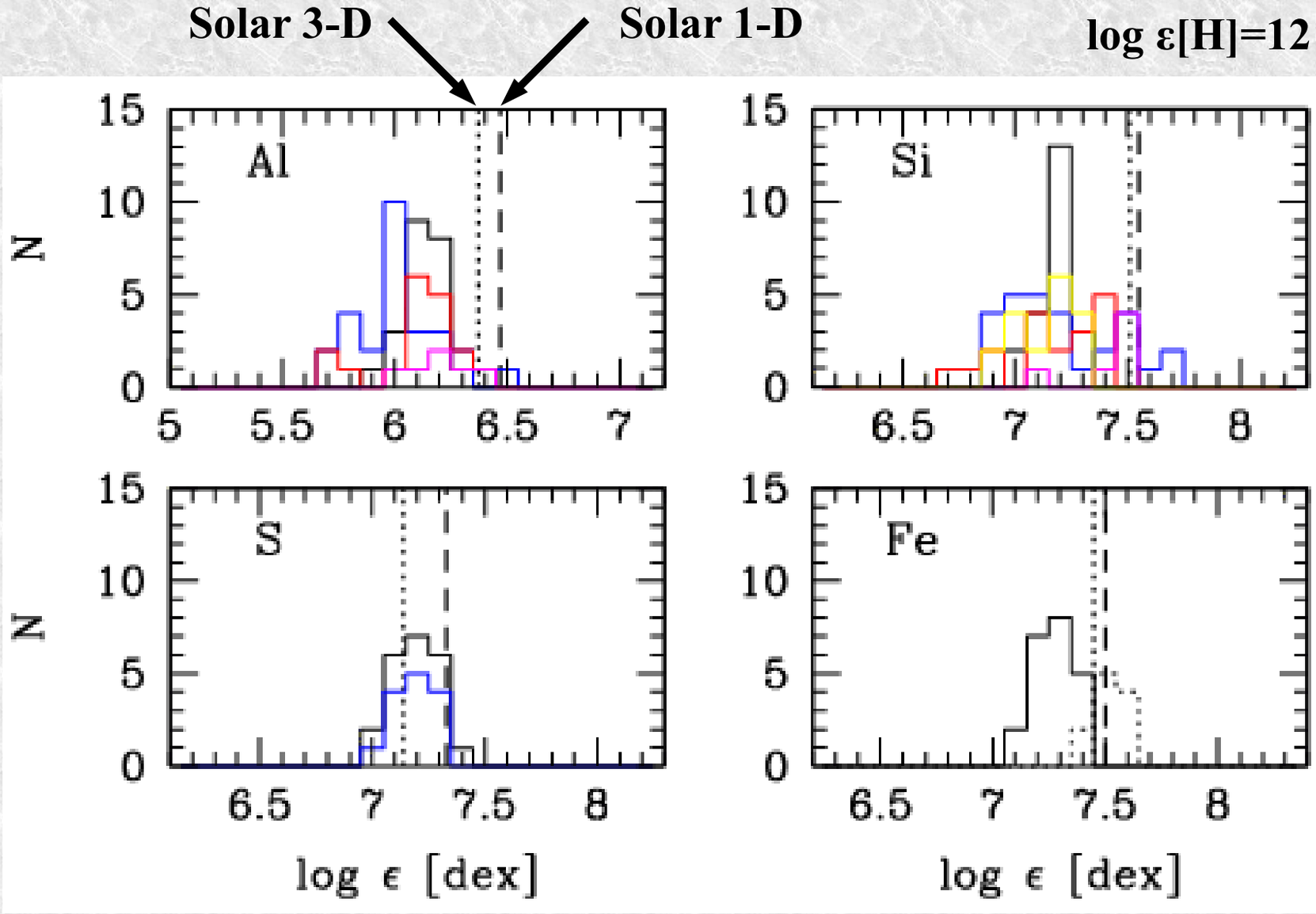
Chemical composition of nearby OB stars: solar?



Cunha & Lambert (1994)
Daflon et al. (1999, 2001, 2003)
Gies & Lambert (1992)
Gummersbach et al. (1998)
Kilian (1992, 1994)
Morel et al. (2008)
Nieva & Przybilla (2008)

..... Lyubimkov et al. (2005)

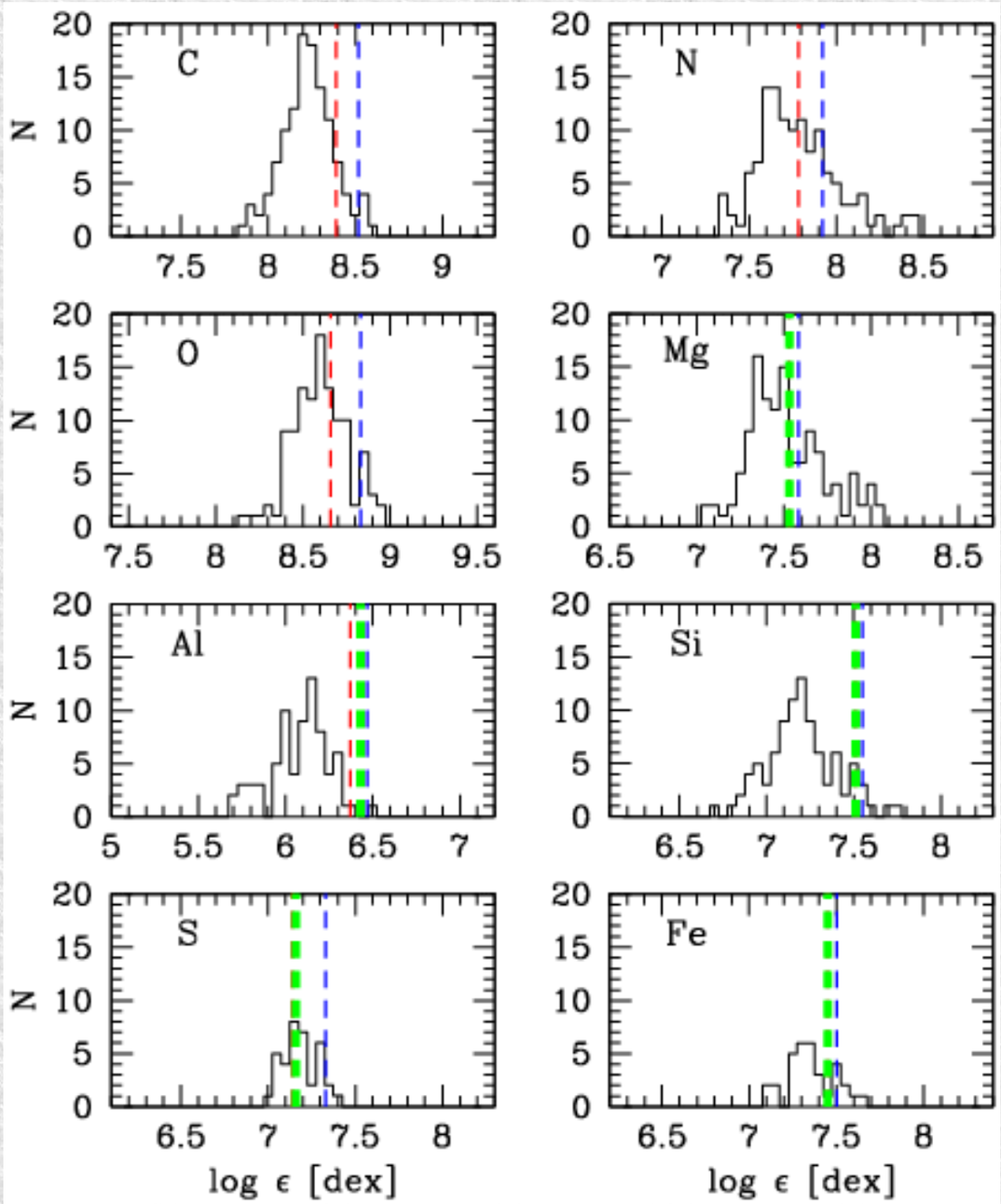
Chemical composition of nearby OB stars: solar?



Cunha & Lambert (1994)
Daflon et al. (1999, 2001, 2003)
Gummersbach et al. (1998)
Kilian (1992, 1994)
Morel et al. (2008)

..... Thompson et al. (2008)

Chemical composition of nearby OB stars: solar?



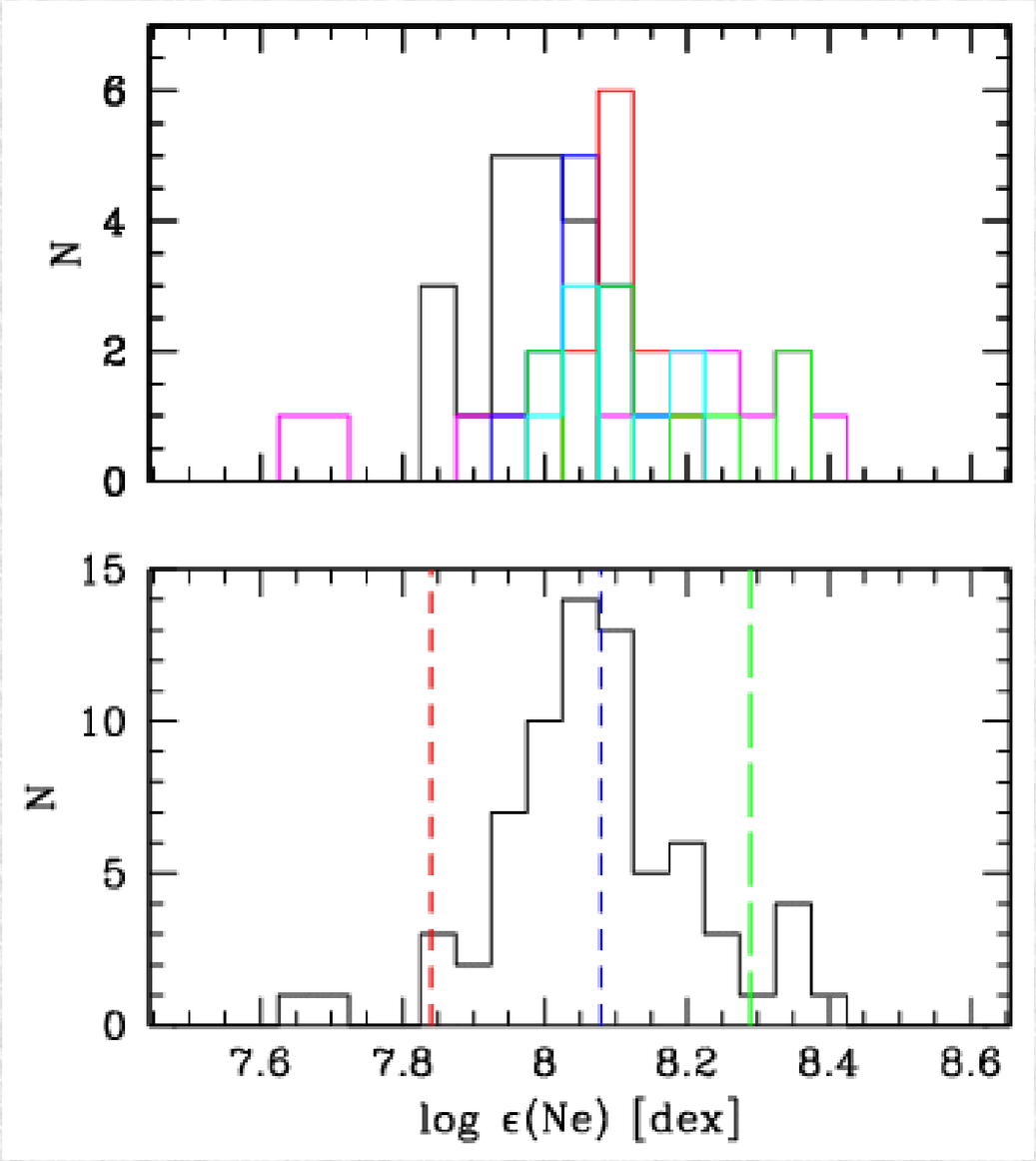
- - - - - Solar 1-D

- - - - - Solar 3-D

- - - - - Meteorites

Abundances of B stars generally below solar!

Chemical composition of nearby OB stars: neon

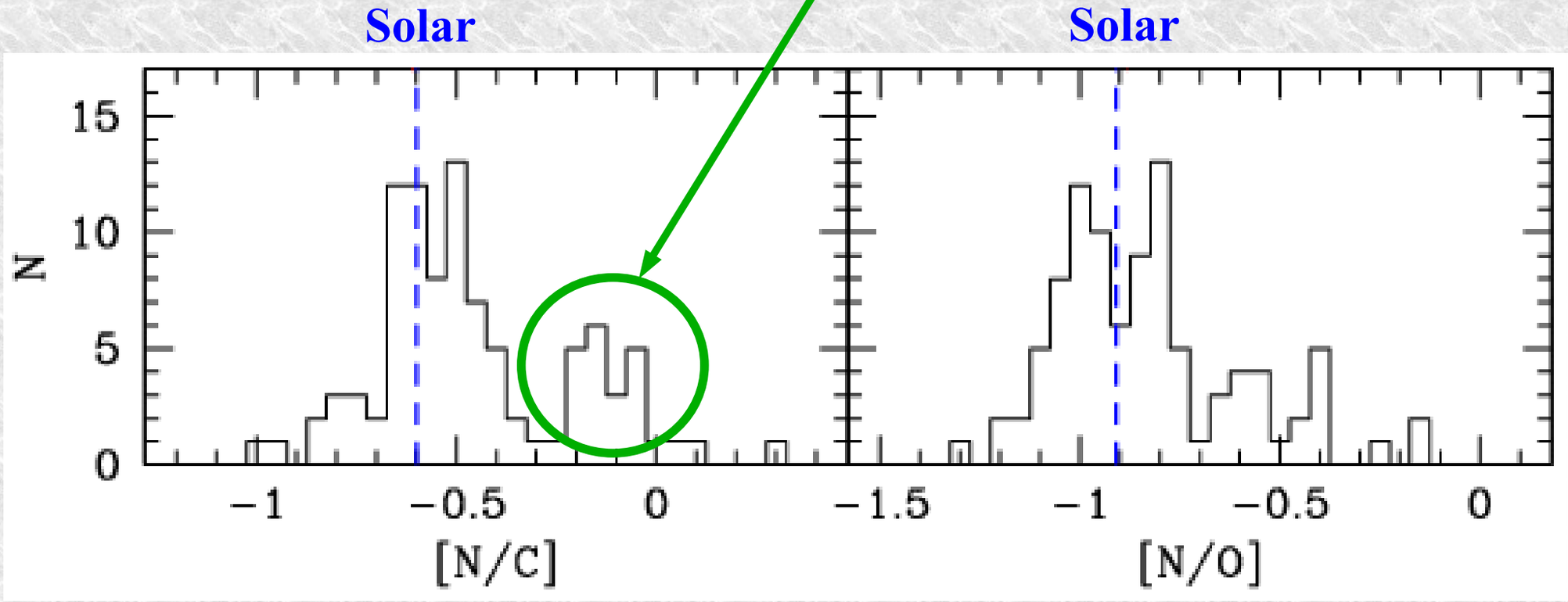


Cunha et al. (2006)
Dworetsky & Budaj (2000)
Hempel & Holweger (2003)
Kilian (1994)
Morel & Butler (2008)
Sigut (1999)

Solar 3-D
Solar 1-D
Value necessary to solve the 'solar model problem'

Deep mixing in OB stars: CNO

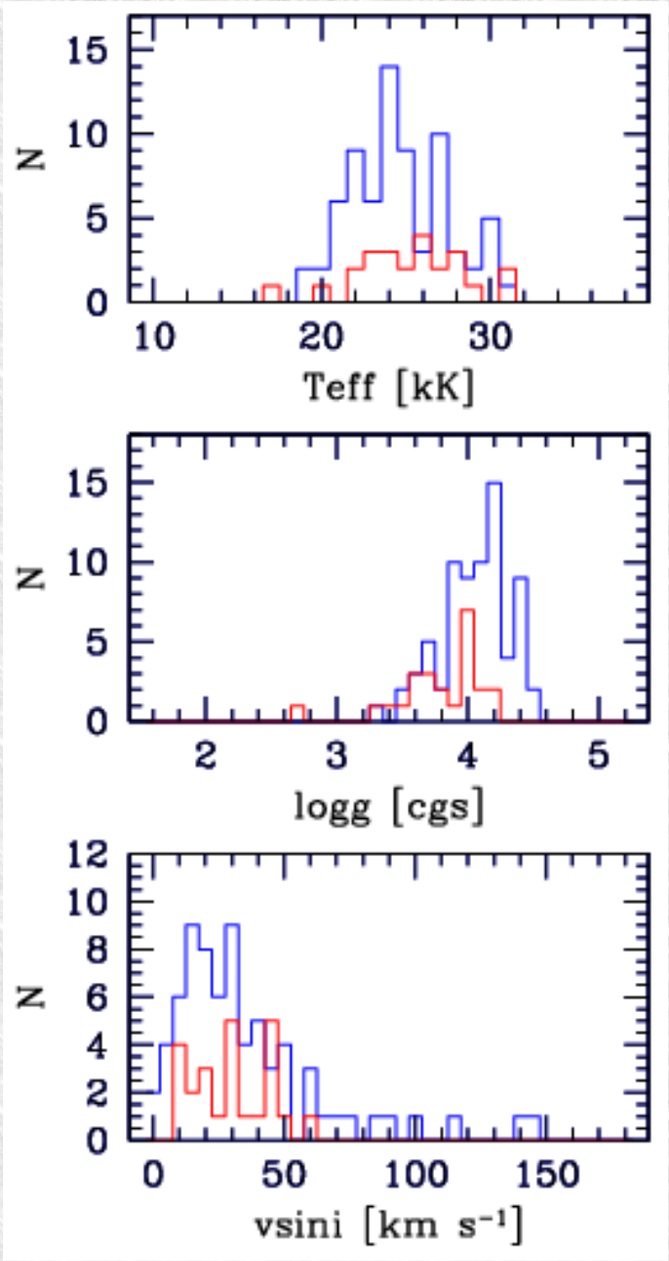
A population of N-enriched main-sequence stars



Deep mixing in OB stars: CNO

N-normal stars:
[N/C]<-0.3 dex

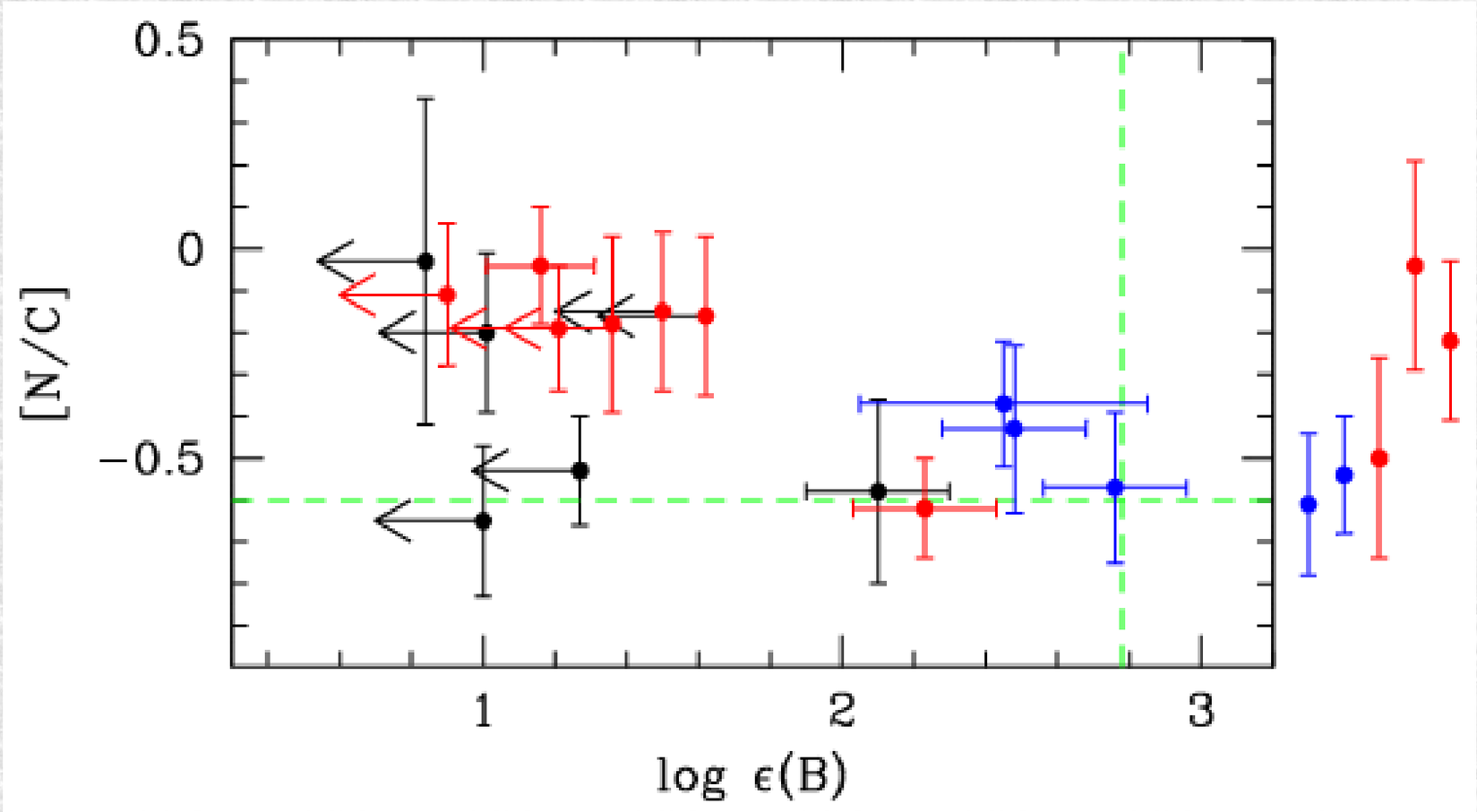
N-rich stars:
[N/C]>-0.3 dex



Δlogg~0.25 dex: evolutionary effect?

Deep mixing in OB stars: a link with magnetic fields?

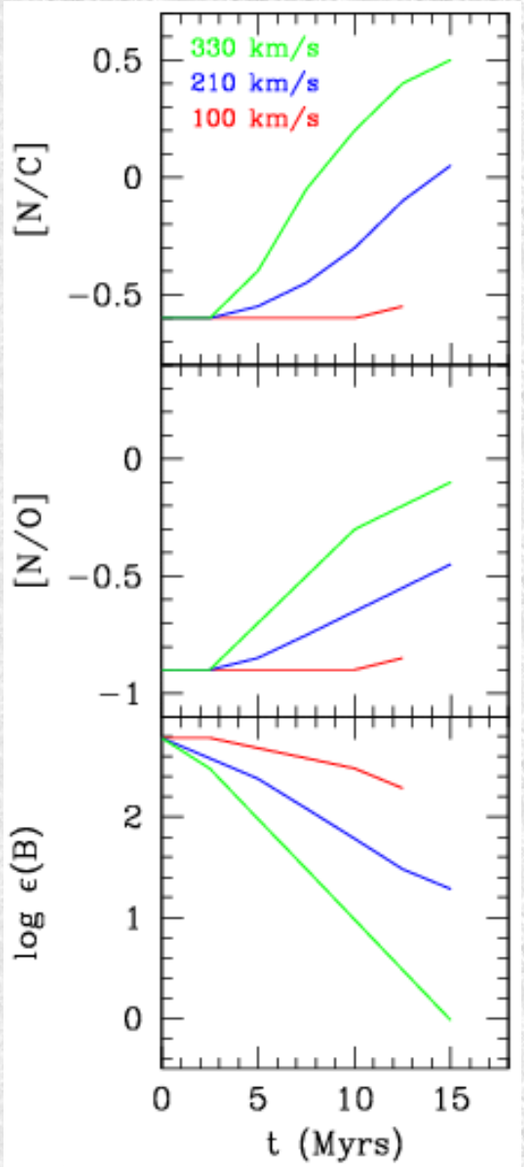
- - - - - - Solar values



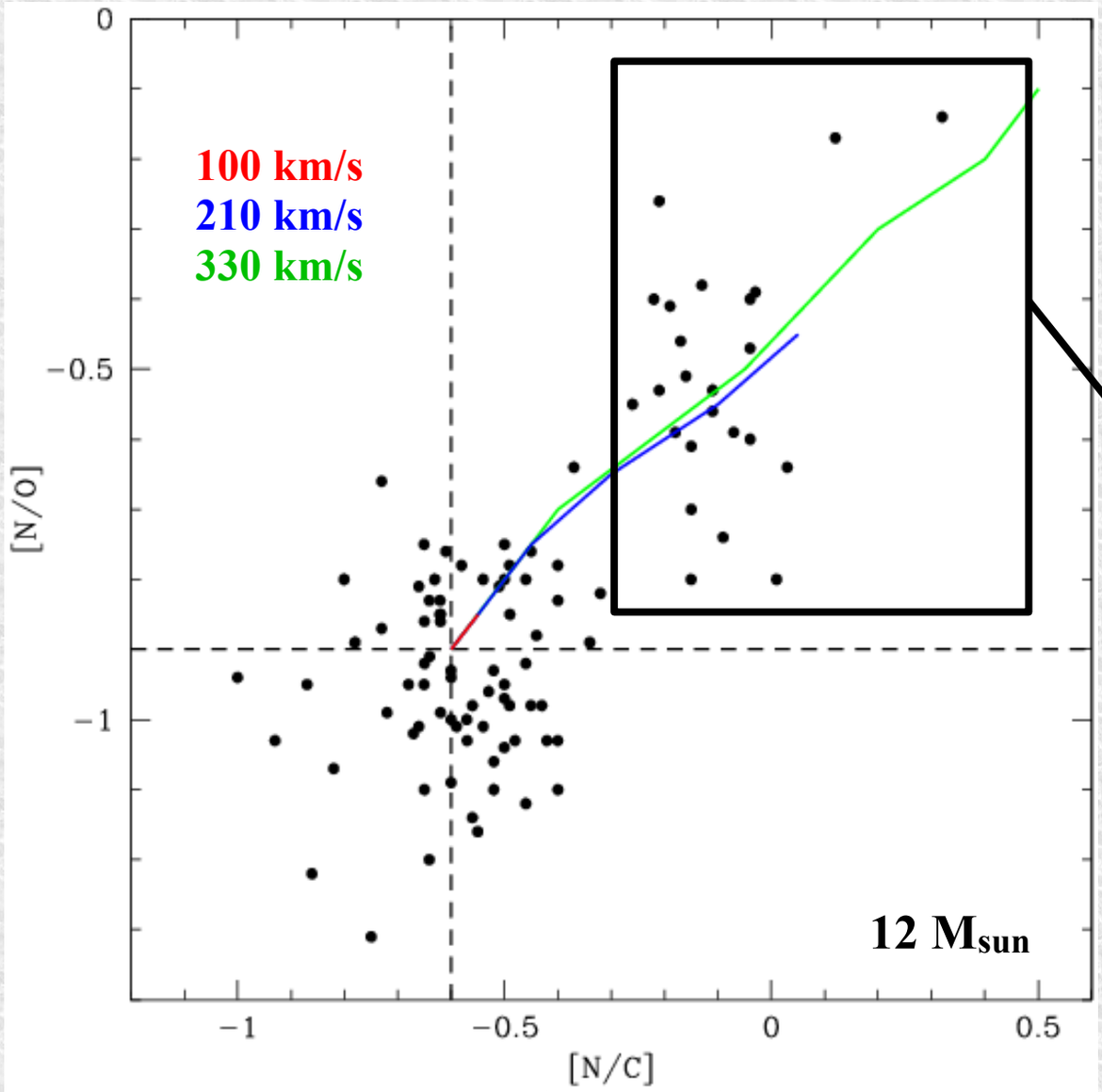
No field detection
With field detection

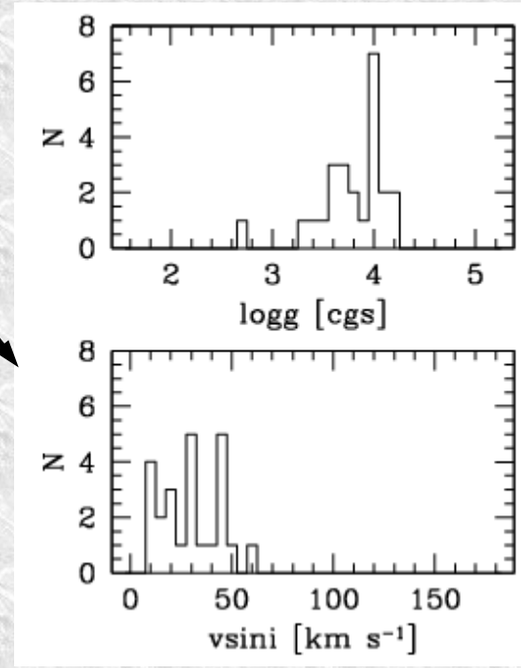
Morel et al. (2008)

Deep mixing in OB stars: confrontation with models



Heger & Langer (2000)

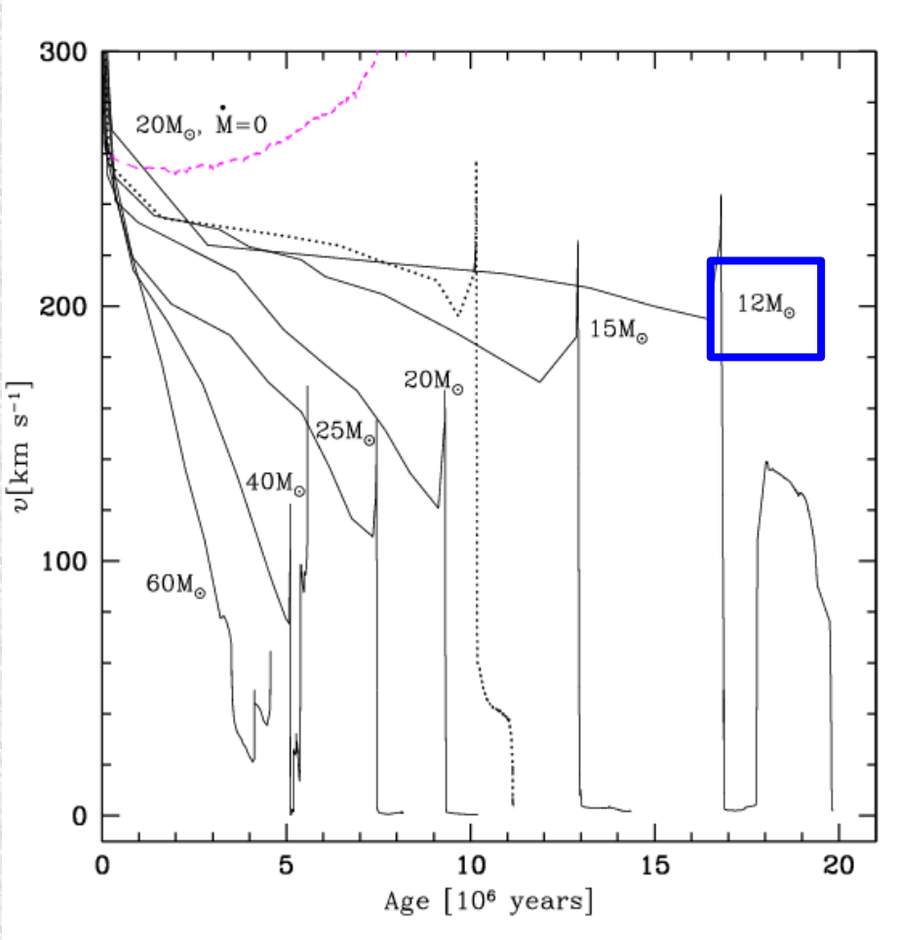




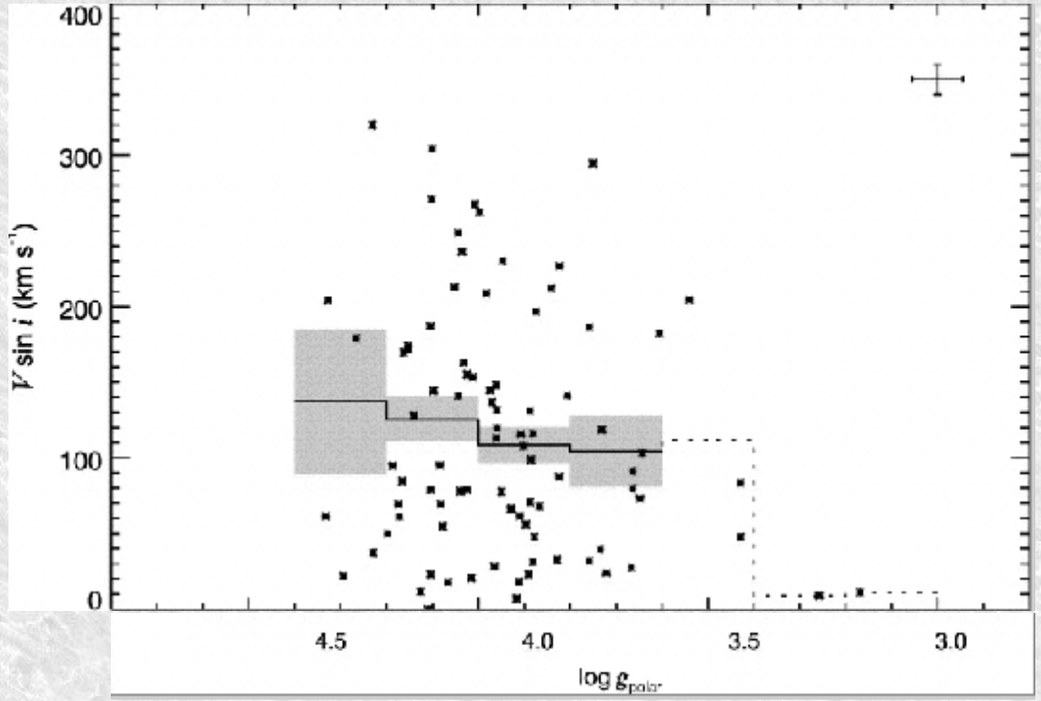
v(ZAMS)~200 km/s needed but <vsini>~30 km/s only

Deep mixing in OB stars: confrontation with models

Only a modest decrease of the rotational velocities of B stars from ZAMS to TAMS

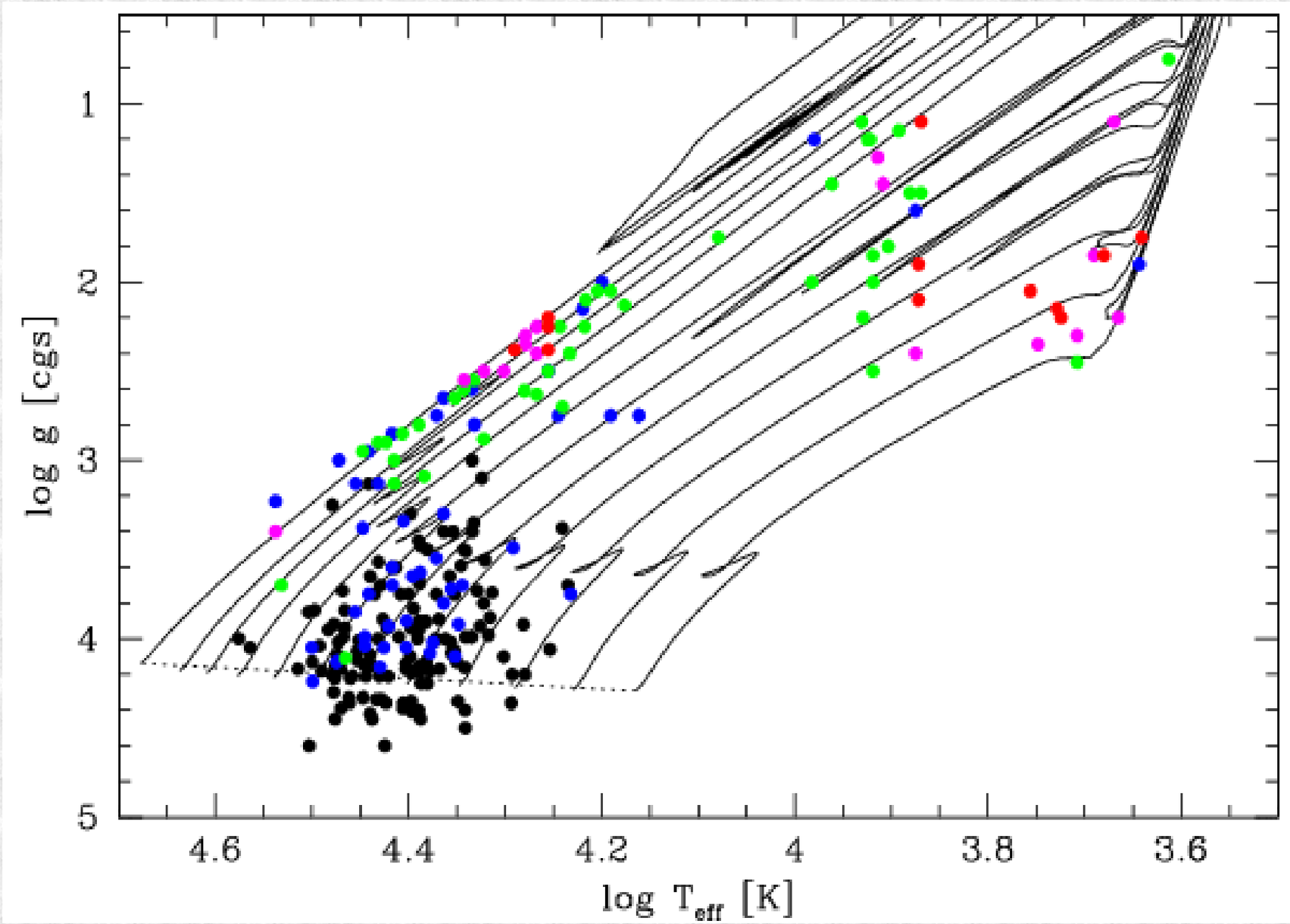


Meynet & Maeder (2003)



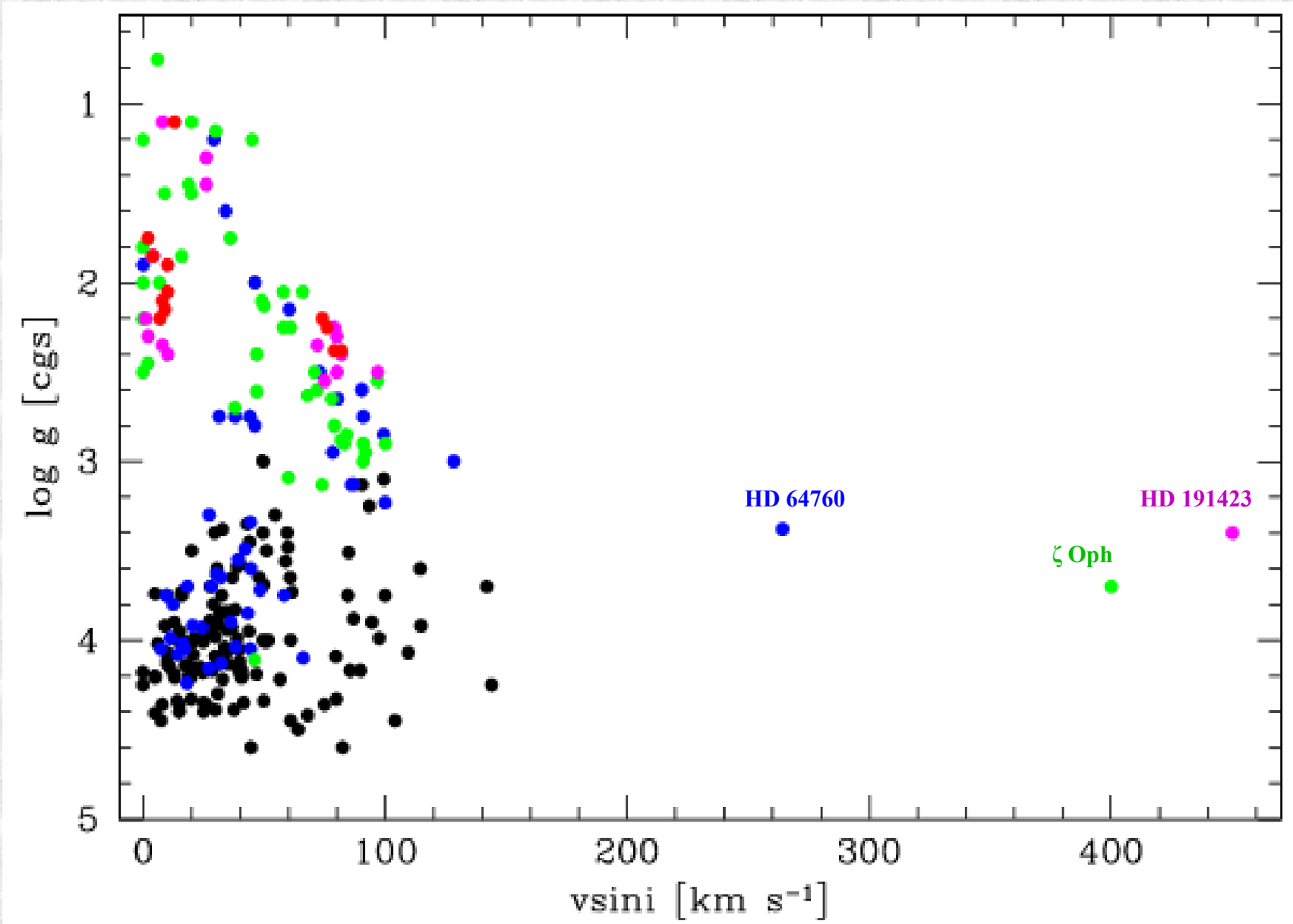
Huang & Gies (2006)

Deep mixing in OB stars: Galaxy



[N/C]<-0.2
-0.2<[N/C]<+0.2
+0.2<[N/C]<+0.6
+0.6<[N/C]<+1.0
[N/C]>+1.0

Deep mixing in OB stars: Galaxy



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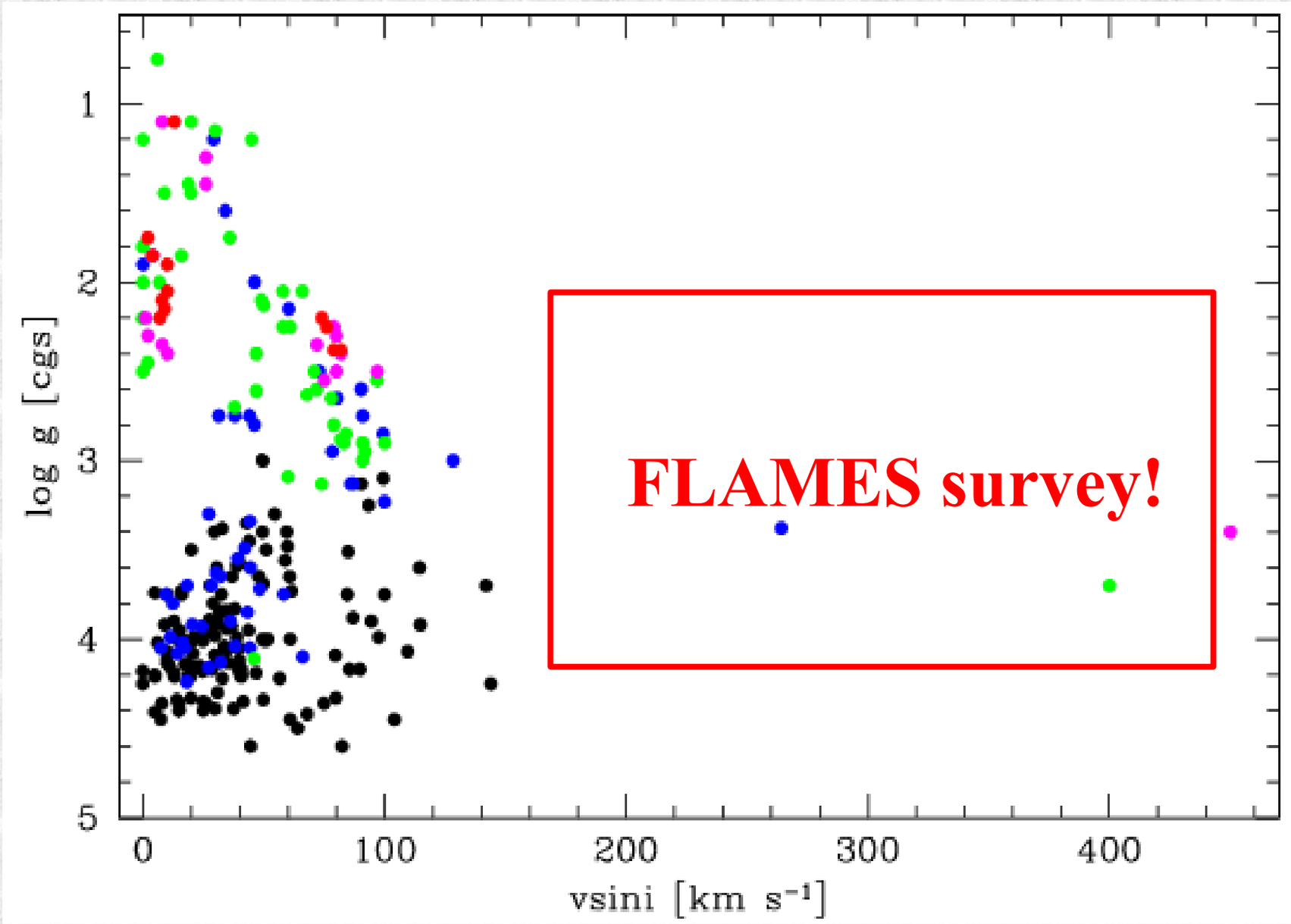
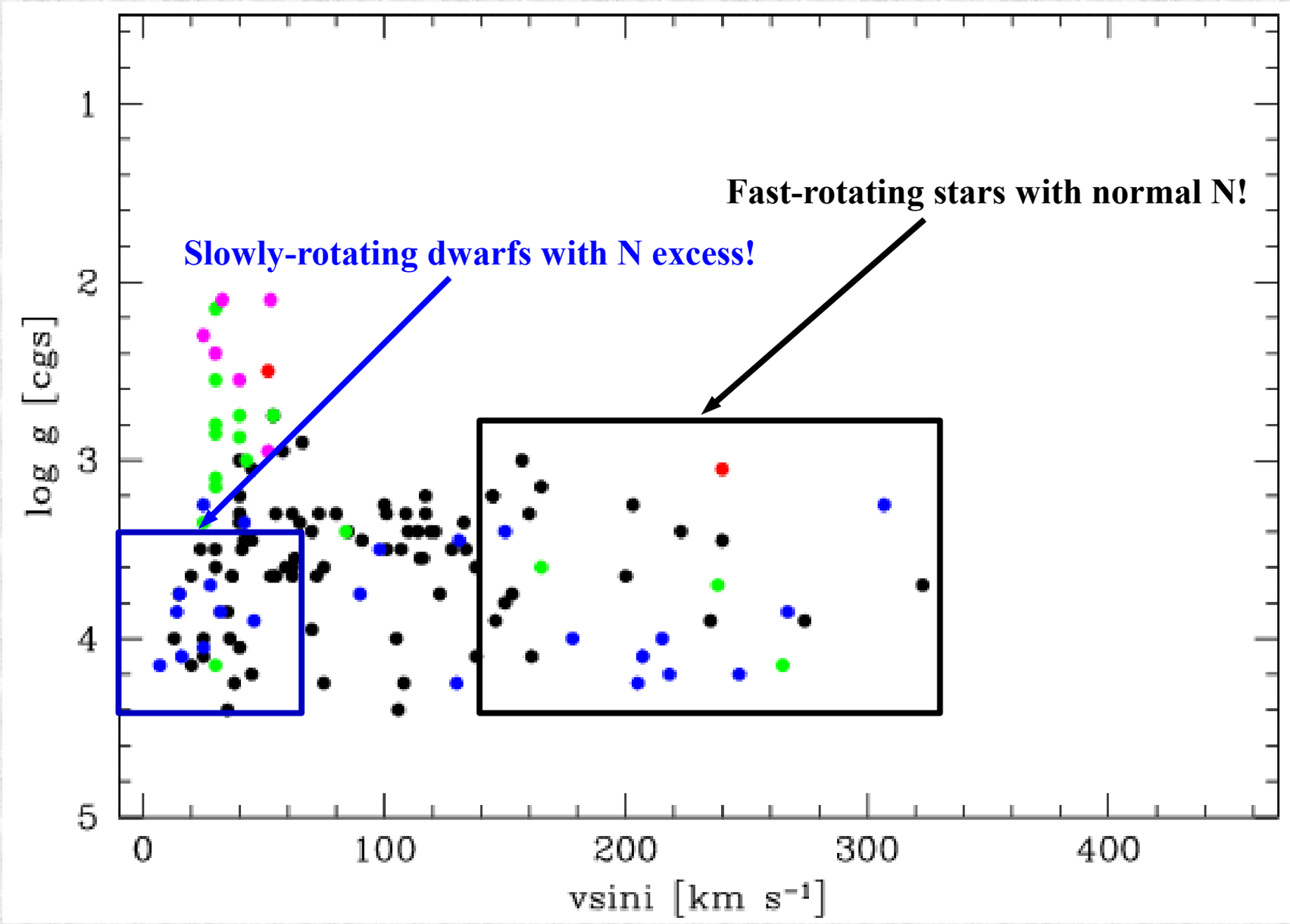


[N/C]<-0.2
-0.2<[N/C]<+0.2
+0.2<[N/C]<+0.6
+0.6<[N/C]<+1.0
[N/C]>+1.0

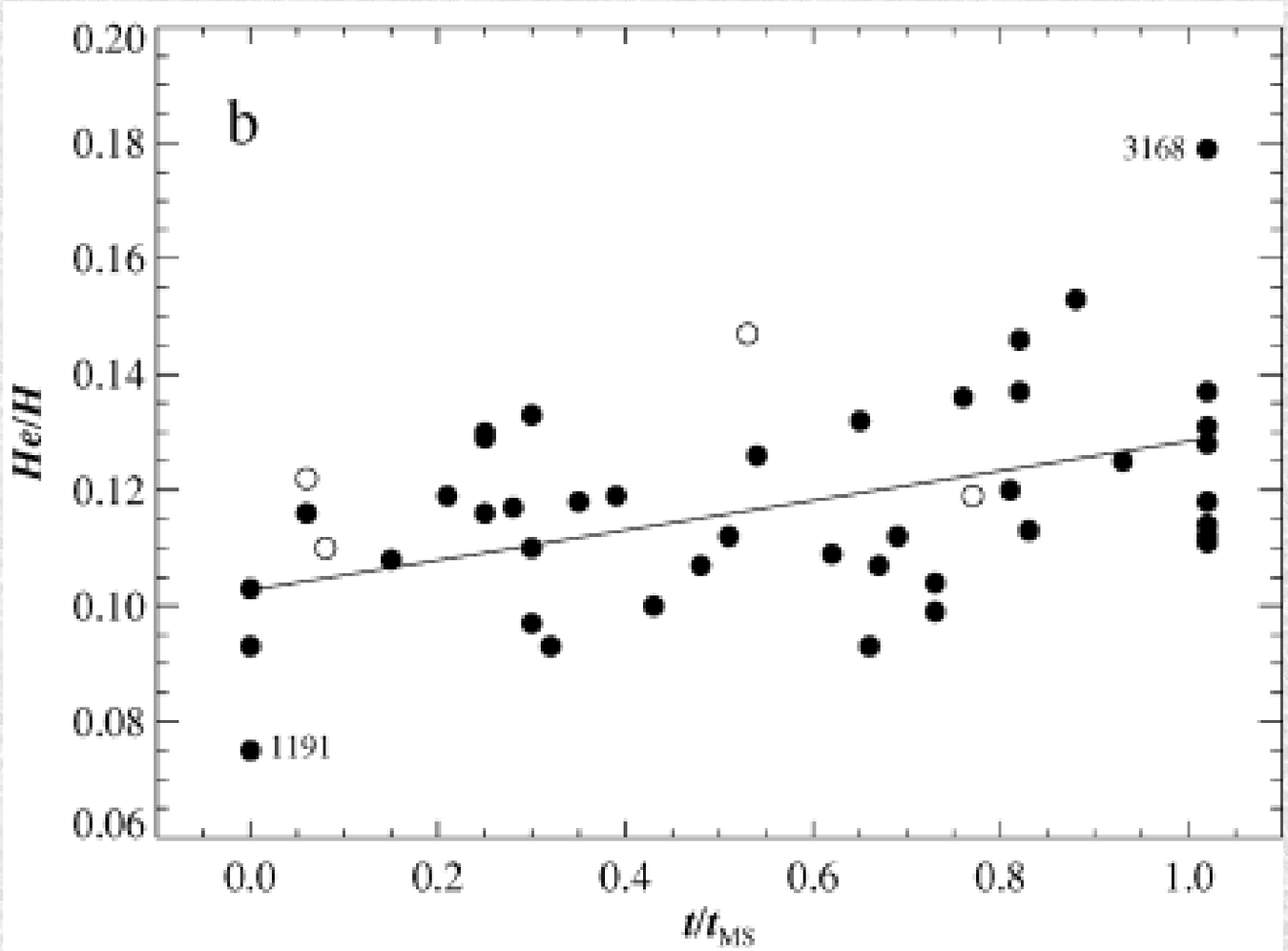
Deep mixing in OB stars: LMC



[N/C]<-0.45
-0.45<[N/C]<-0.05
-0.05<[N/C]<+0.35
+0.35<[N/C]<+0.75
[N/C]>+0.75

Hunter et al. (2008)

Deep mixing in OB stars: He



Lyubimkov et al. (2004)

Conclusions

Chemical composition of nearby OB stars

- Abundance studies strongly biased towards early B-type stars:
  data for O stars and late B-type stars (diffusion effects) desirable
- Metal abundances of OB stars likely underestimated: Z~0.010

Deep mixing in OB stars

- He, B, CNO: powerful probes of mixing processes
- Clear evolutionary effects
- Two populations not explained by rotational mixing:
  - Slowly-rotating, N-rich dwarfs: mixing efficiency underestimated?
    stronger loss of angular momentum than expected? magnetic fields?
  - Fast-rotating stars with normal nitrogen in LMC (and in the Galaxy?)
- Needed in the future:
  - Establishing the nature of these two subsamples
  - Abundance data for fast rotators