Chemical abundances of Blue Straggler stars in Galactic Globular Clusters

LOREDANA LOVISI
Physics & Astronomy Department – Bologna University

Cosmic-Lab

www.cosmic-lab.eu

erc

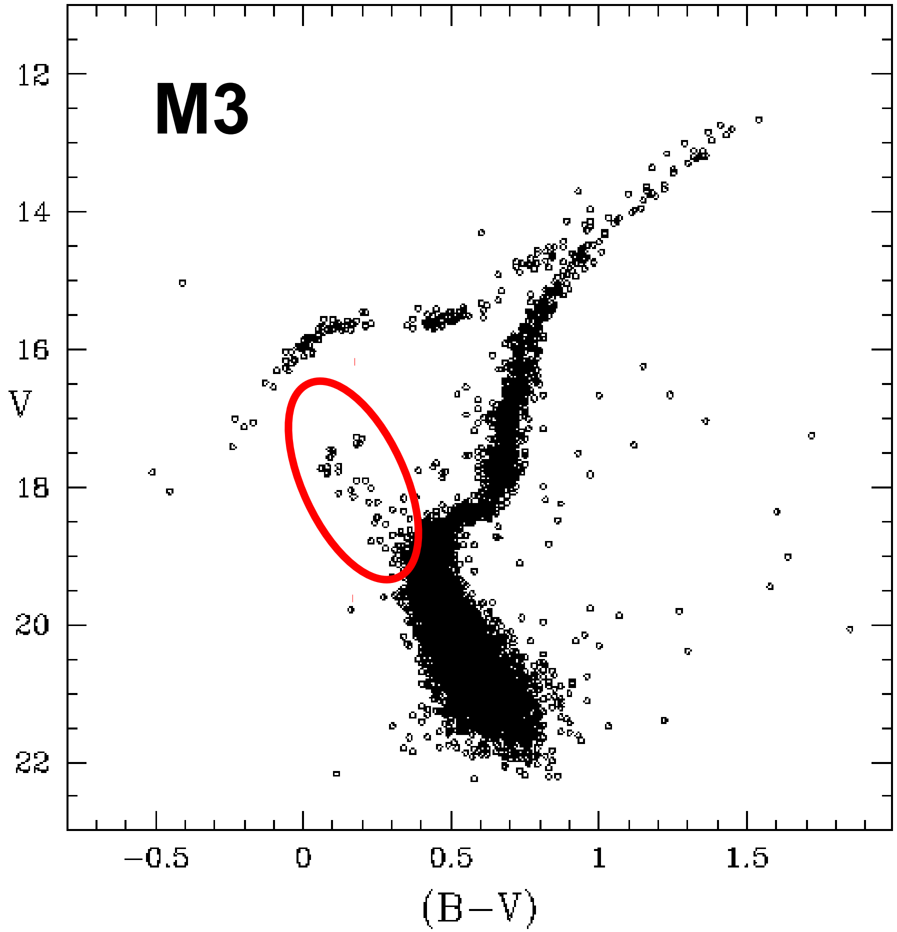
Cosmic-Lab

- 5-year project
- funded by the European Research Council (ERC)
- PI: Francesco R. Ferraro (Dip. of Physics & Astronomy – Bologna Univ.)
- AIM: **to understand the complex interplay between dynamics & stellar evolution**
- HOW: using **globular clusters** as cosmic laboratories and

Blue Straggler Stars
Millisecond Pulsars
Intermediate-mass Black Holes

as probe-particles

Blue Straggler stars (BSS)



Discovered by Sandage (1953)

Brighter and bluer (hotter) than Main Sequence stars

More massive than TO
(Shara et al, 1997)

BSS mimic a
rejuvenated stellar population

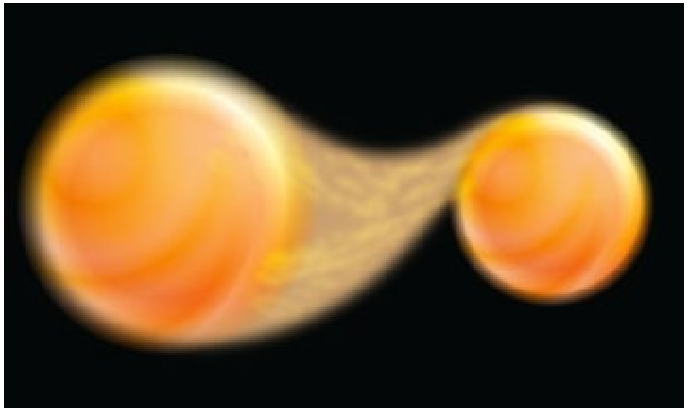
The chemical composition of BSS

Searching for chemical signatures
of the BSS formation mechanisms

Mass Transfer BSS

C & O depletion expected in the BSS surface

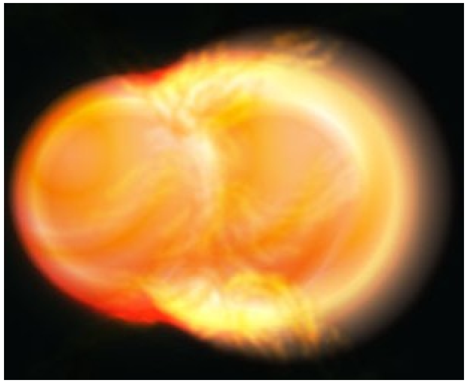
(Sarna & de Greve, 1996)



Collisional BSS

No chemical signatures

(Lombardi et al. 1995)



The spectroscopic dataset

High-res spectra with FLAMES@VLT

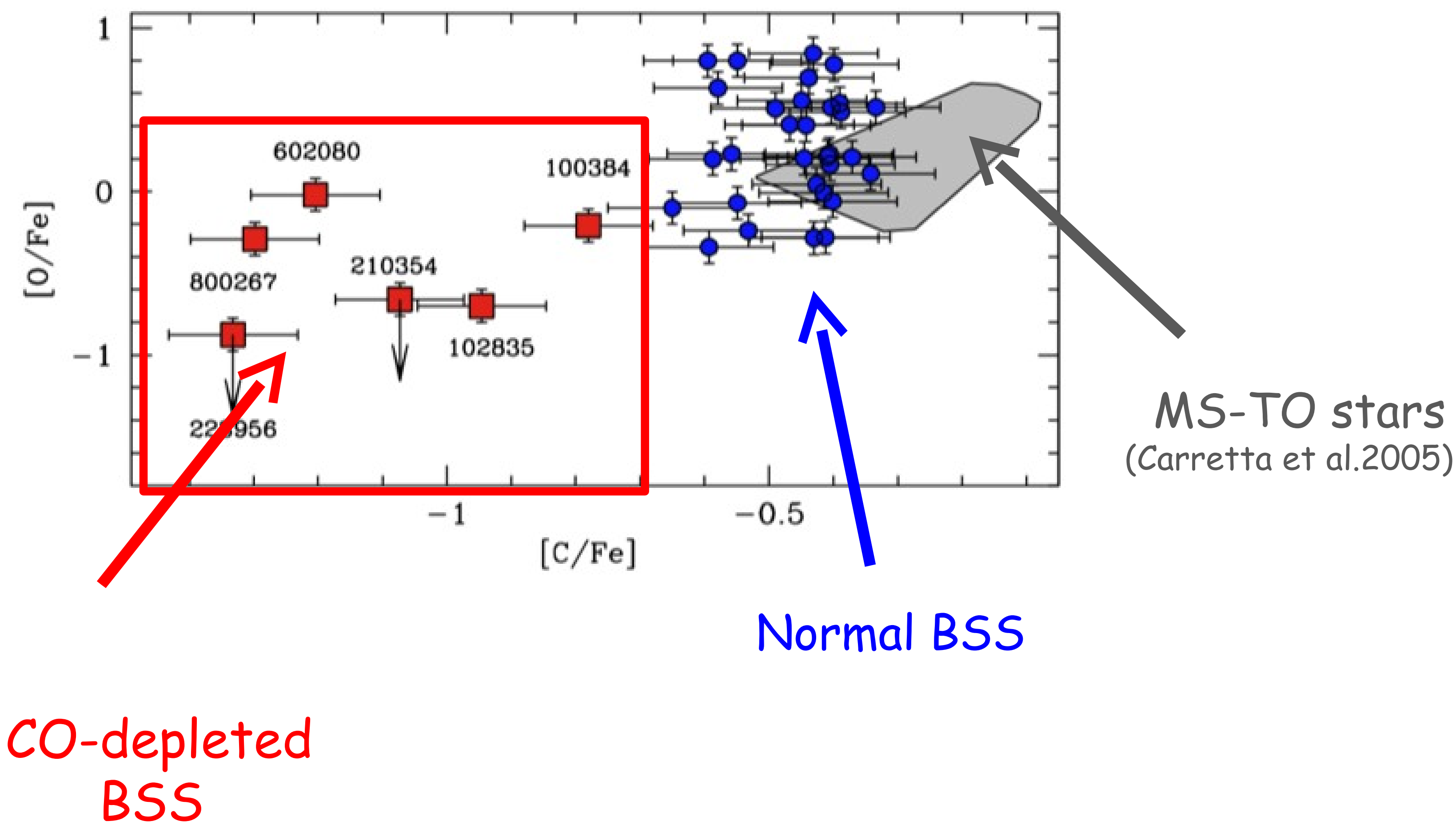
Searching for signatures of mass transfer: C and O

6 GCs

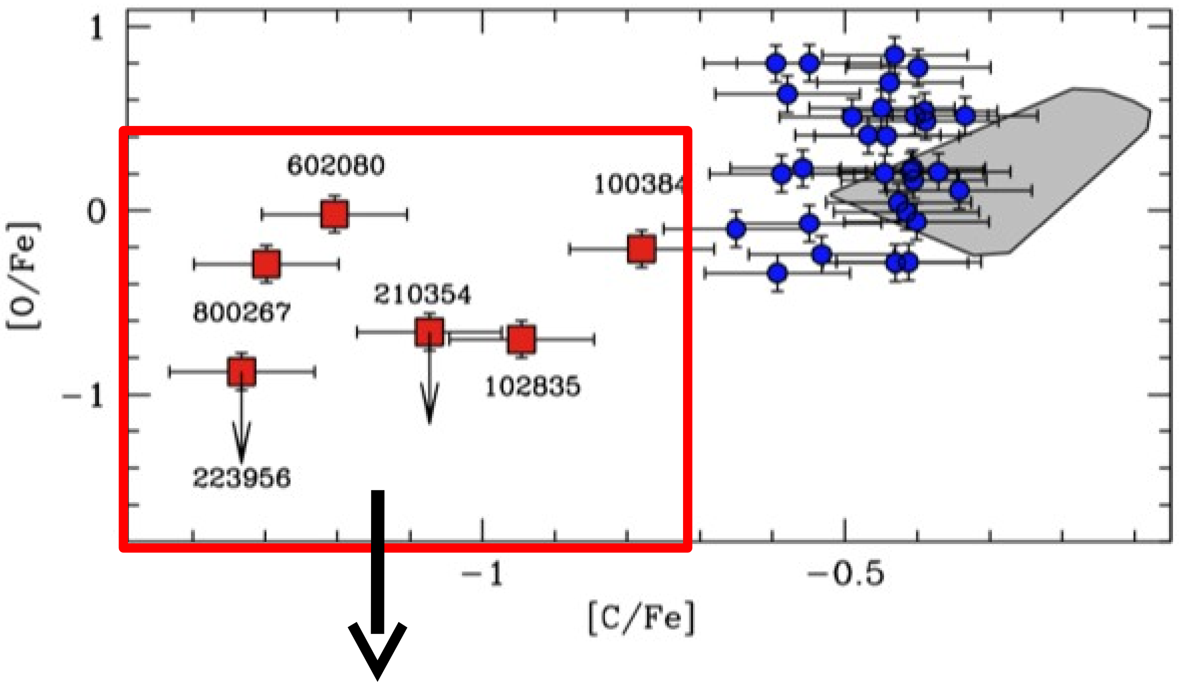
	[Fe/H]		
47 Tuc	-0.7		
M4	-1.1		
NGC 6752	-1.5	PCC	
NGC 6397	-2.0	PCC	
M30	-2.3	PCC	double BSS sequence
Omega Cen	-1.7		non-collisional BSS

47 Tuc

Chemical analysis for 43 BSS (Ferraro et al., 2006)

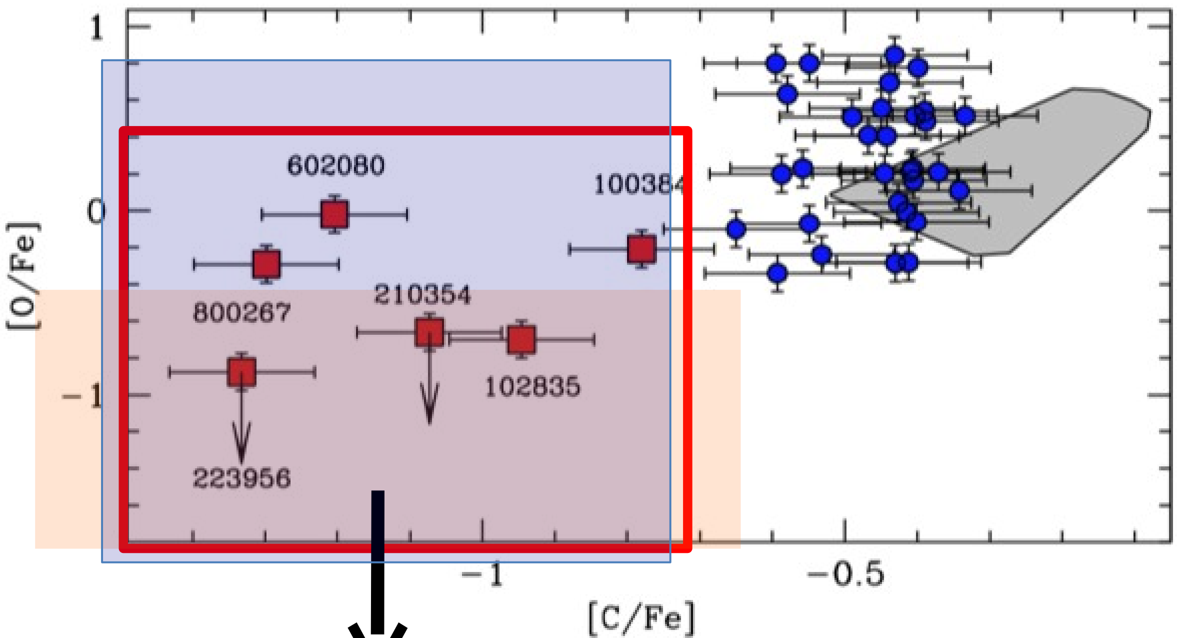


47 Tuc



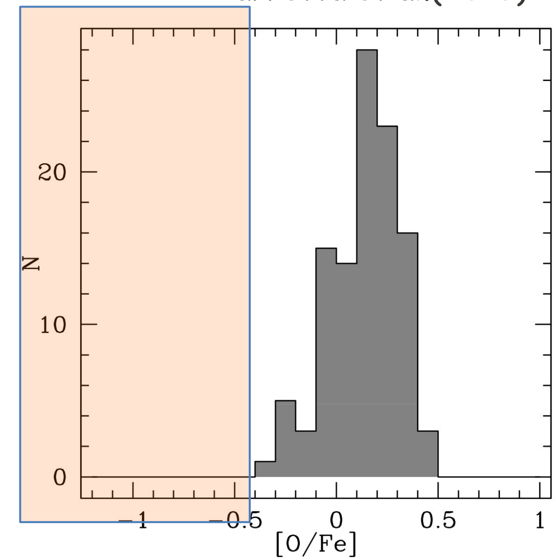
Can be originated from the
second generation stars?

47 Tuc



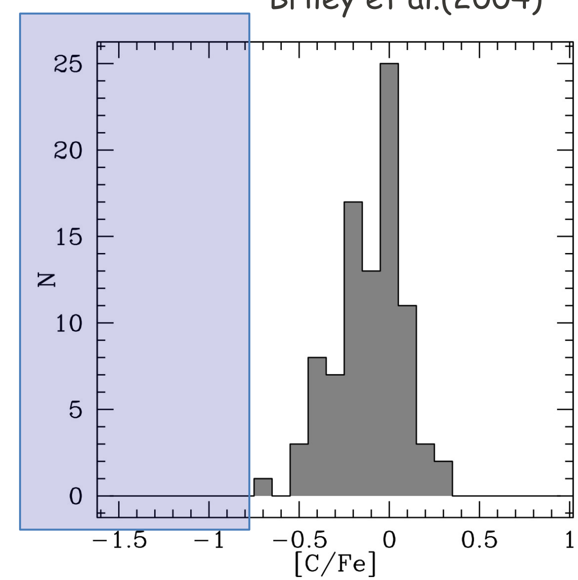
Can be originated from the second generation stars?

Carretta et al.(2010)



No stars with [O/Fe] < -0.4 dex

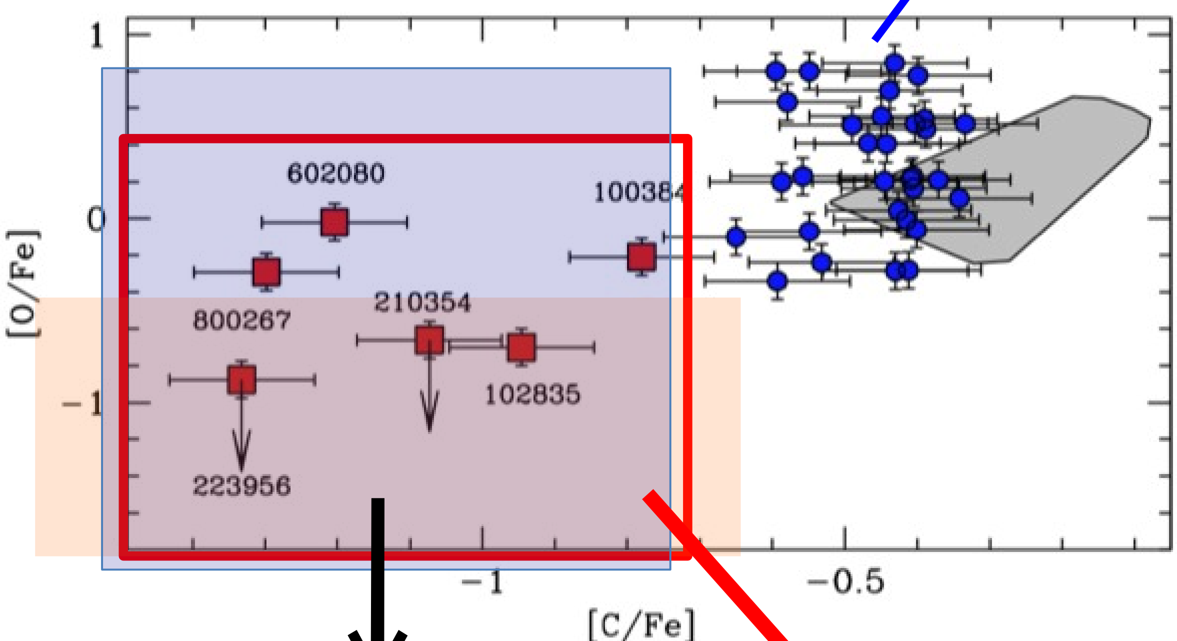
Briley et al.(2004)



No stars with [C/Fe] < -0.8 dex

47 Tuc

COL-BSS

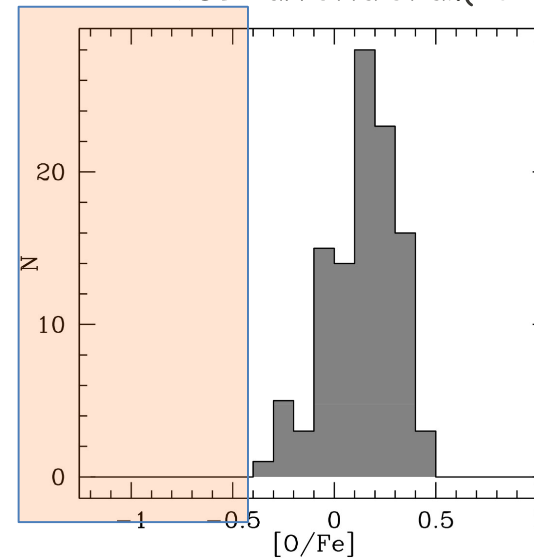


Can be originated from the second generation stars?

NO !!!

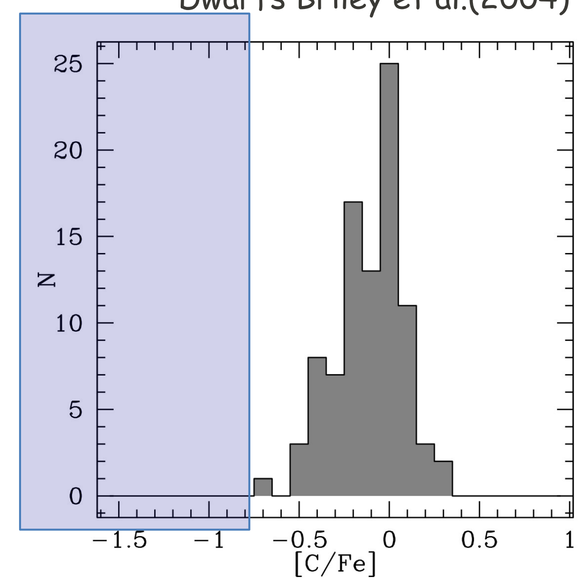
Hint of mass transfer

RGB Carretta et al.(2010)



No stars with [O/Fe] < -0.4 dex

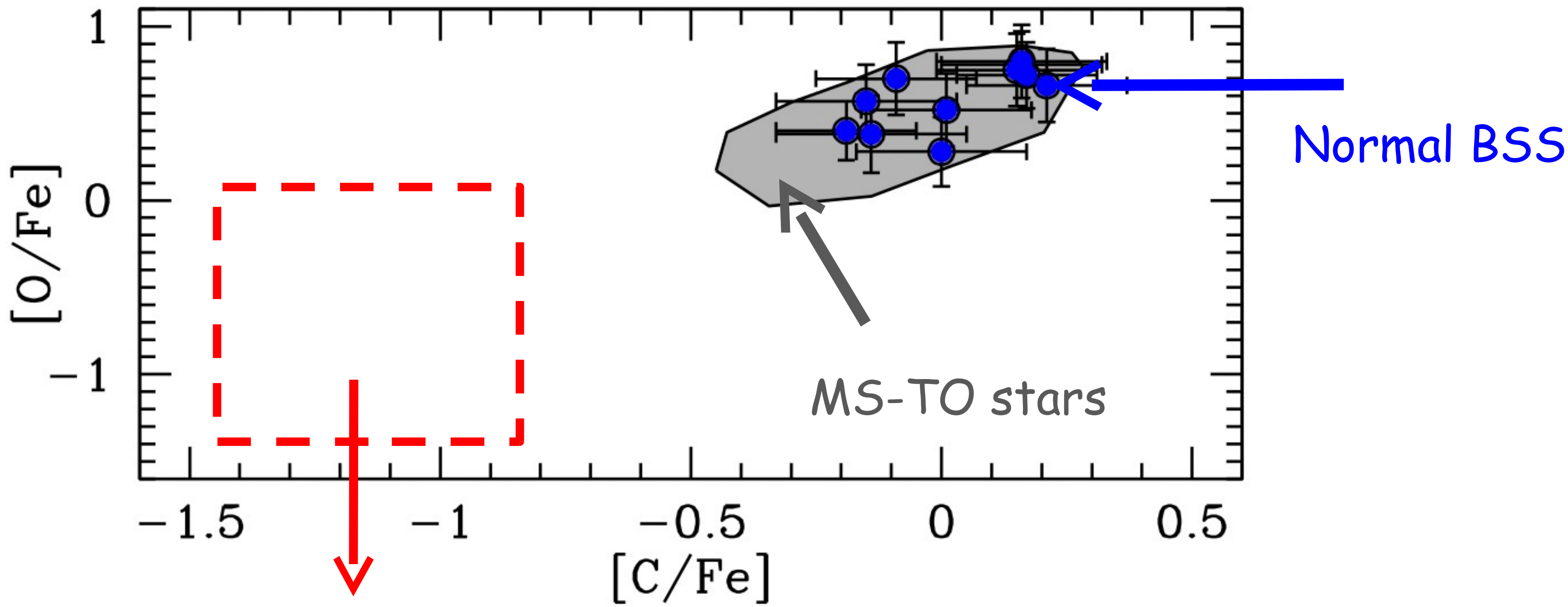
Dwarfs Briley et al.(2004)



No stars with [C/Fe] < -0.8 dex

M4

Chemical analysis for 11 BSS (Lovisi et al.,2010)



No CO-depleted BSS

M4

20 BSS observed but ...

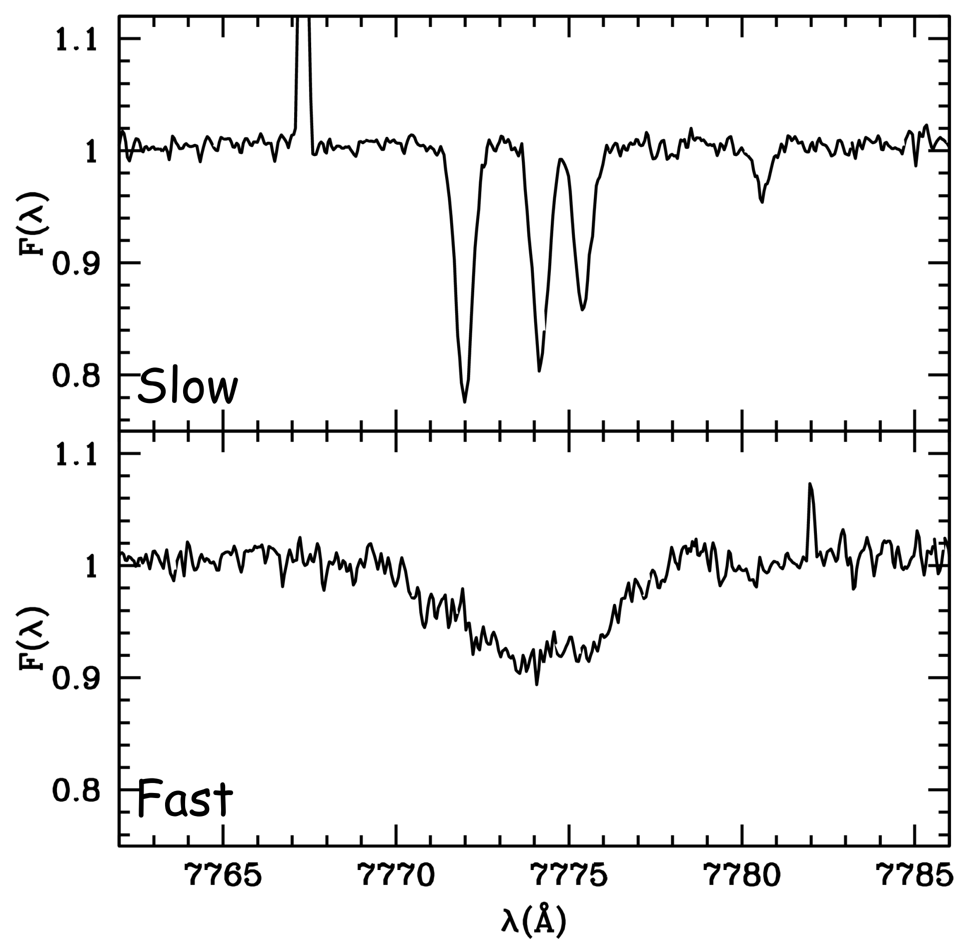
Many fast rotators !!

v sin(i) > 100 km/s

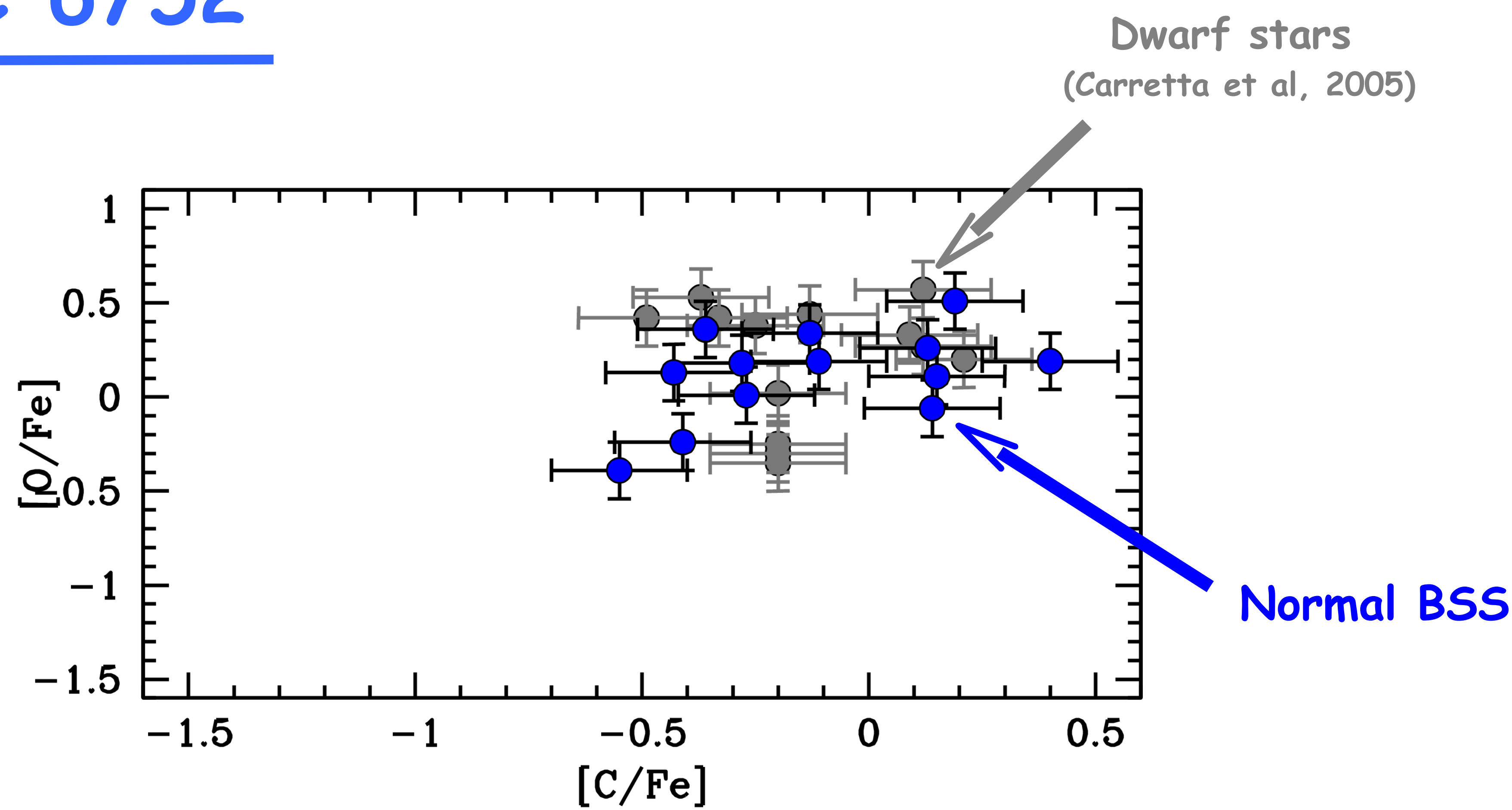
The highest percentage of fast rotating BSS ever found in any GC !!
~40%

Unfortunately
we cannot measure abundances

OI triplet

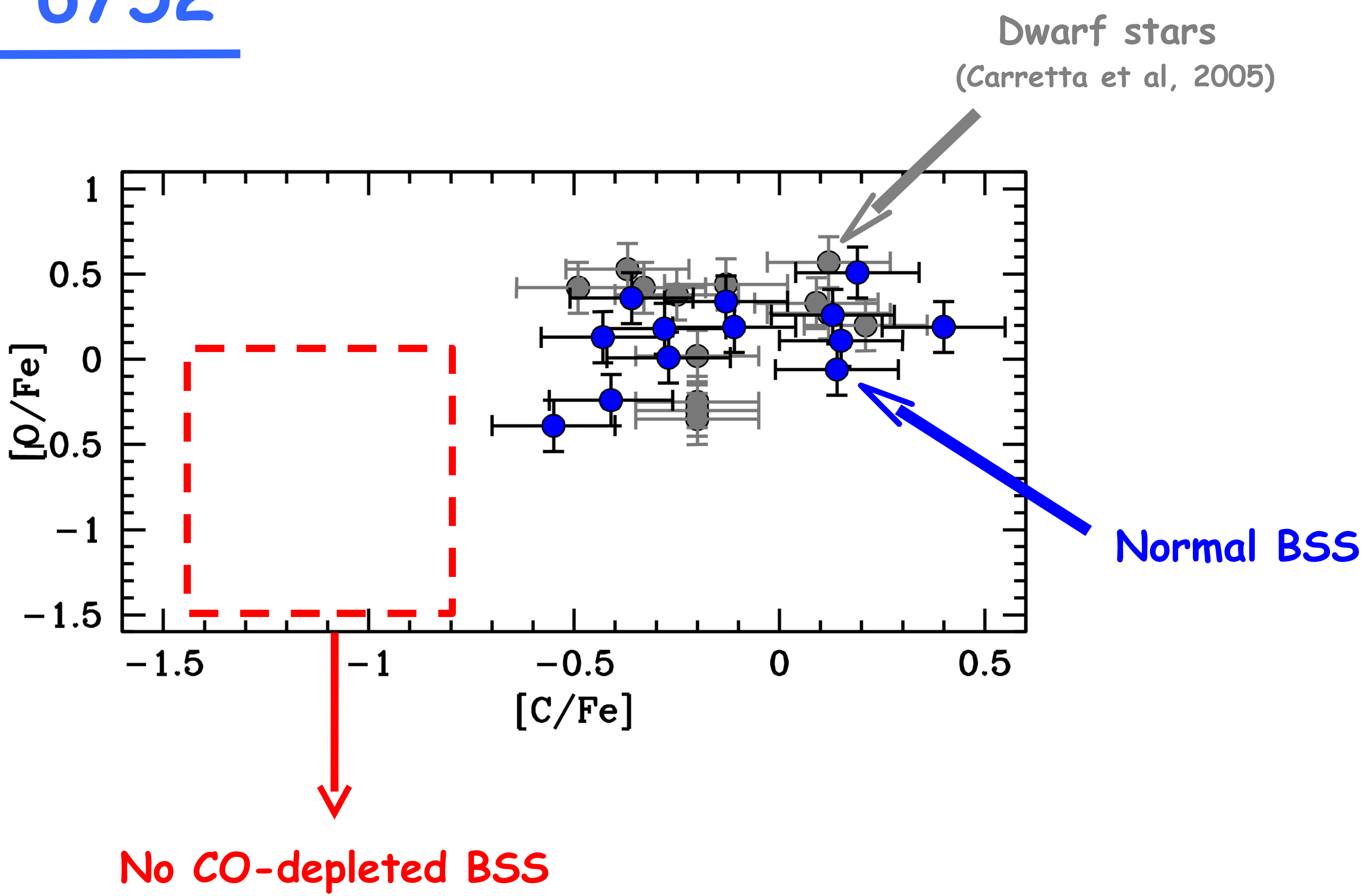


NGC 6752



Dwarf stars
(Carretta et al, 2005)
Normal BSS
[O/Fe]
[C/Fe]
1
0.5
0
−0.5
−1
−1.5
−1.5
−1
−0.5
0
0.5

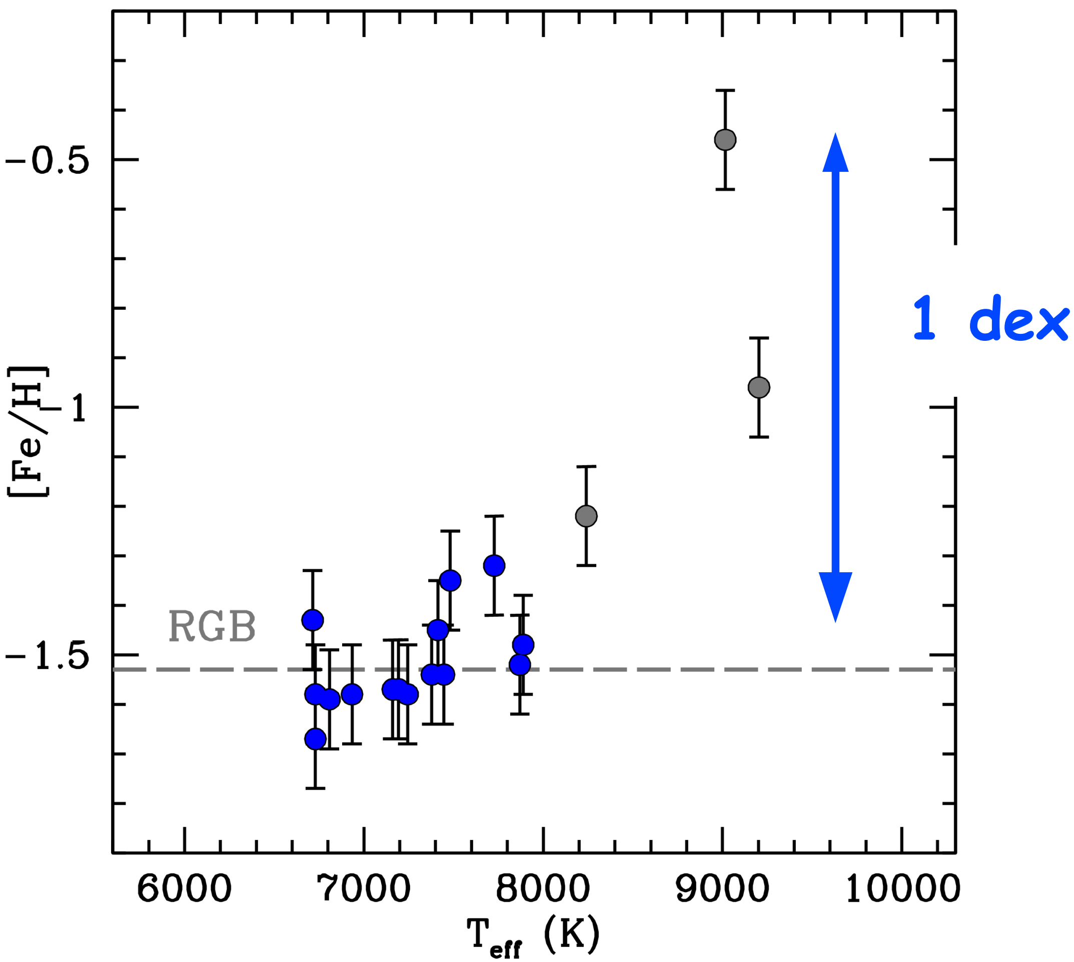
NGC 6752



Dwarf stars
(Carretta et al, 2005)
Normal BSS
No CO-depleted BSS
[O/Fe]
[C/Fe]

NGC 6752

Chemical analysis for 18 BSS (Lovisi et al.,2013b)

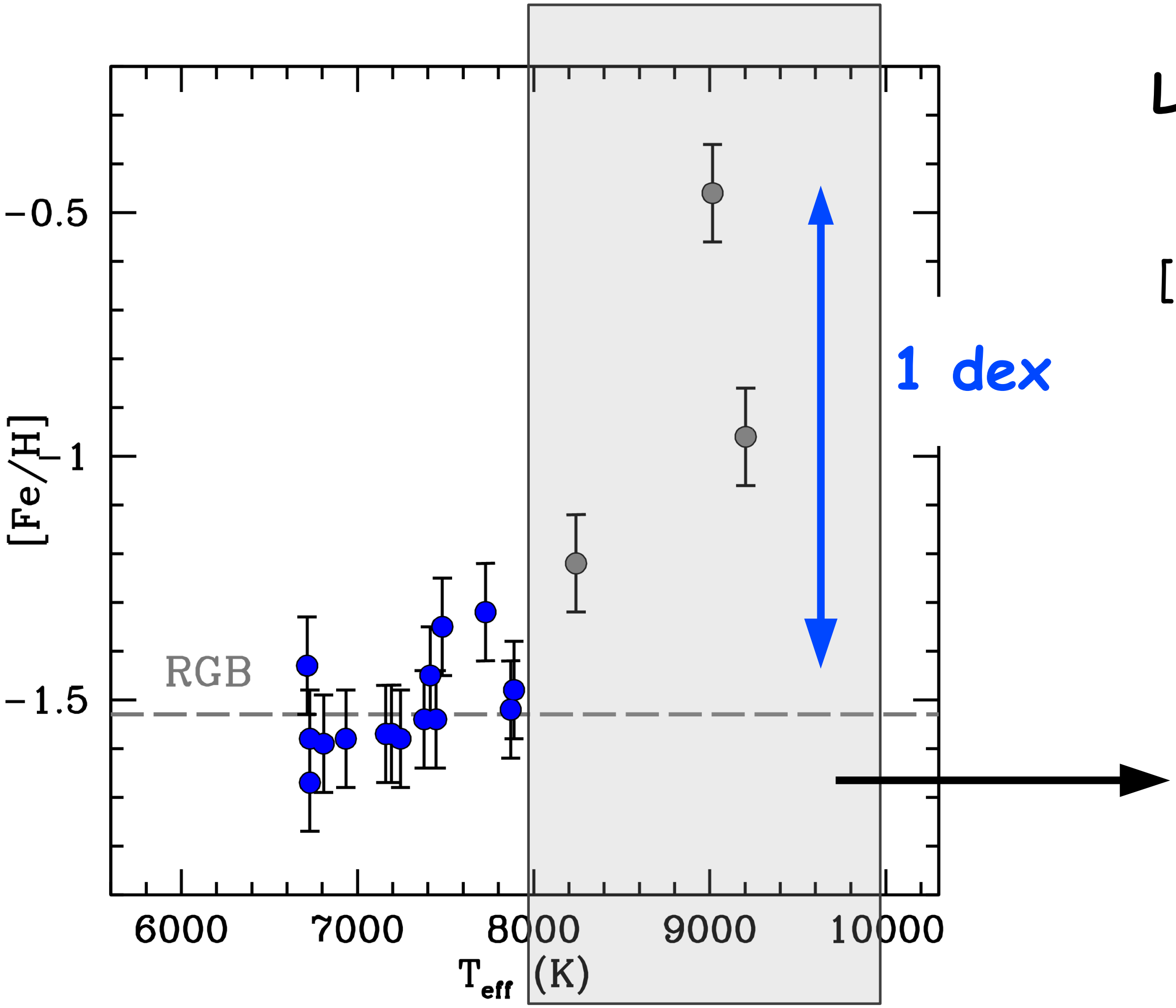


Large spread in [Fe/H]

[Fe/H] increases with Teff

NGC 6752

Chemical analysis for 18 BSS (Lovisi et al.,2013b)



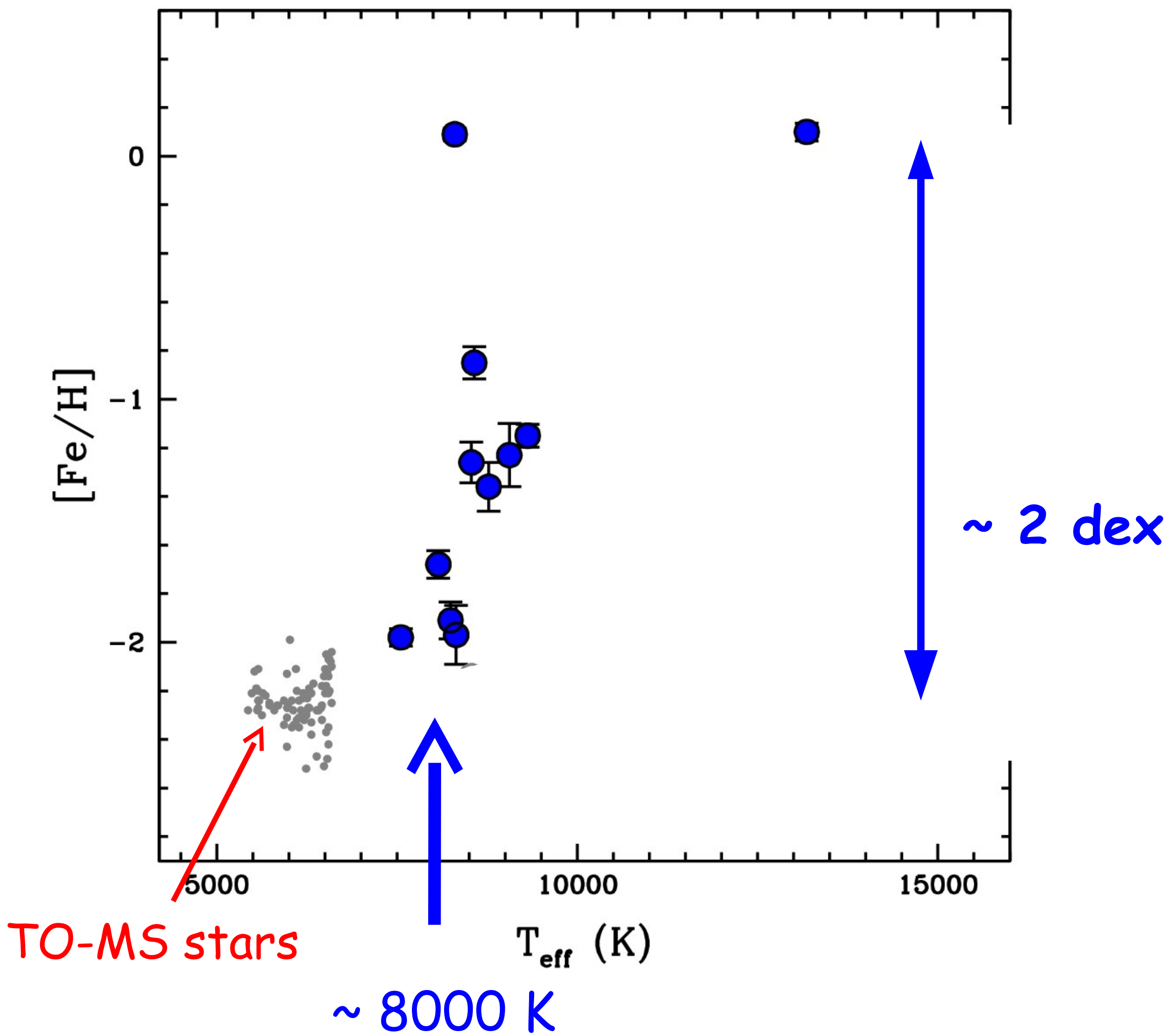
Large spread in [Fe/H]

[Fe/H] increases with Teff

What happens to these stars?

NGC 6397

Chemical analysis for 11 BSS (Lovisi et al.,2012)



Large spread in [Fe/H]

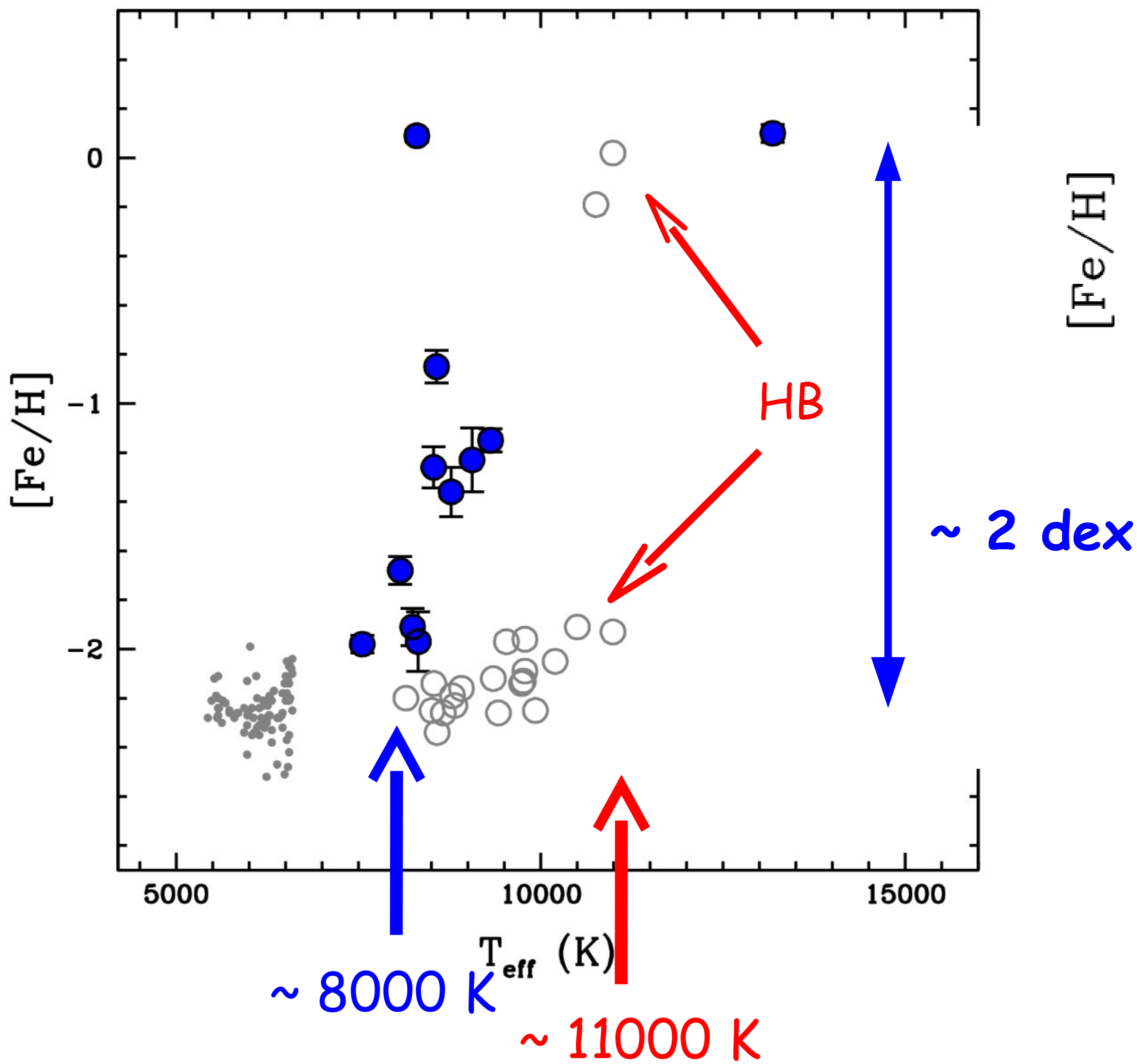
[Fe/H] increases with Teff

NGC 6397

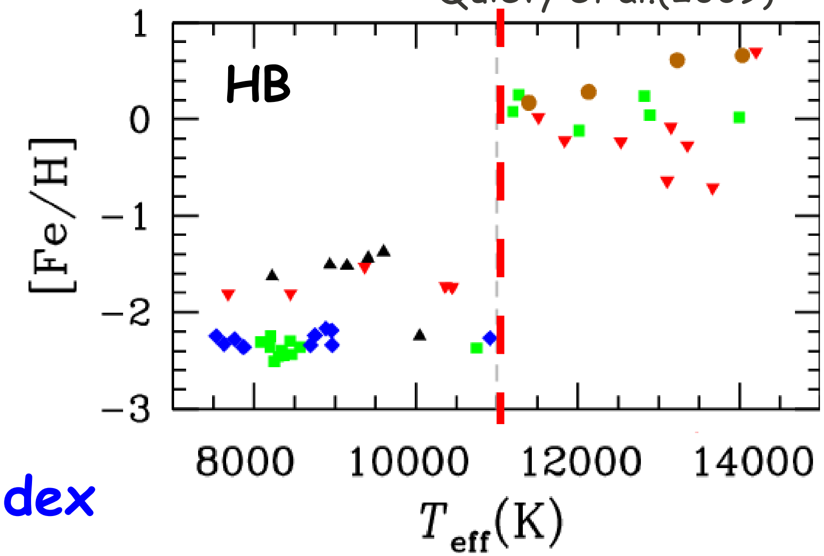
Radiative levitation !!

observed in HB stars

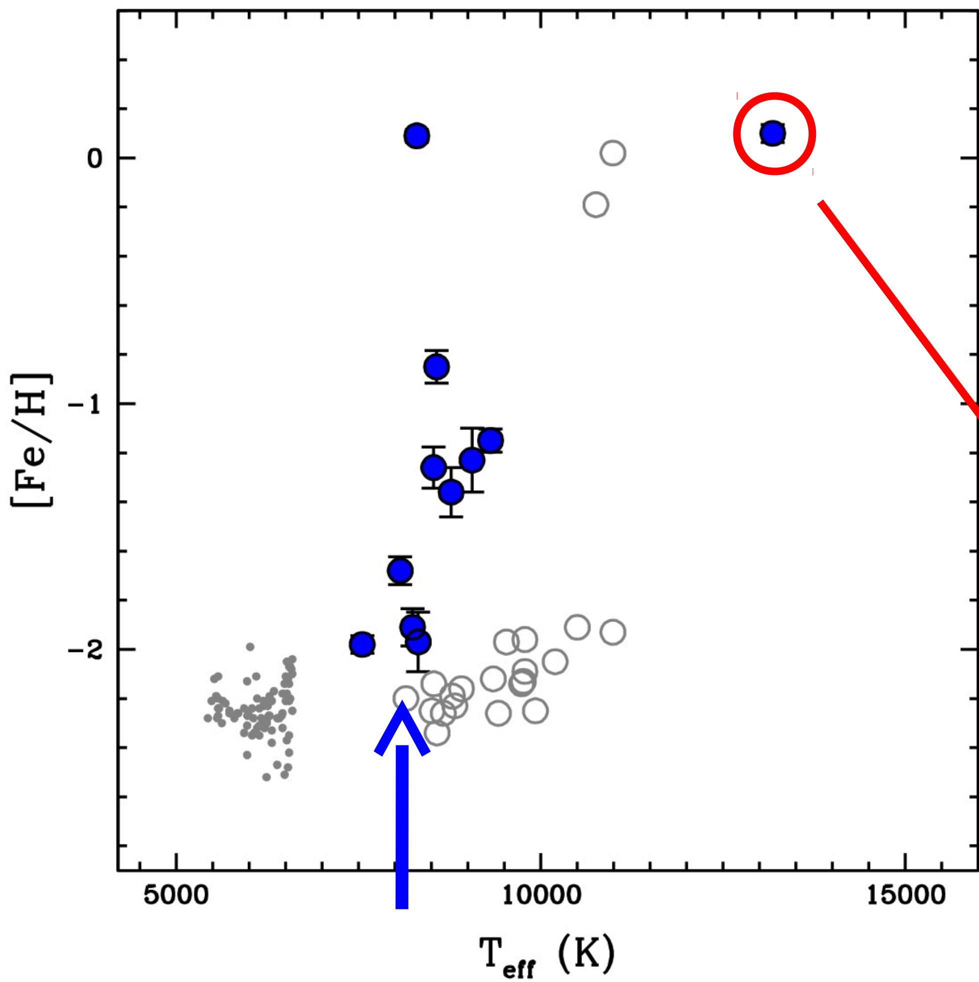
with Teff> 11000 K



Quievy et al.(2009)



NGC 6397



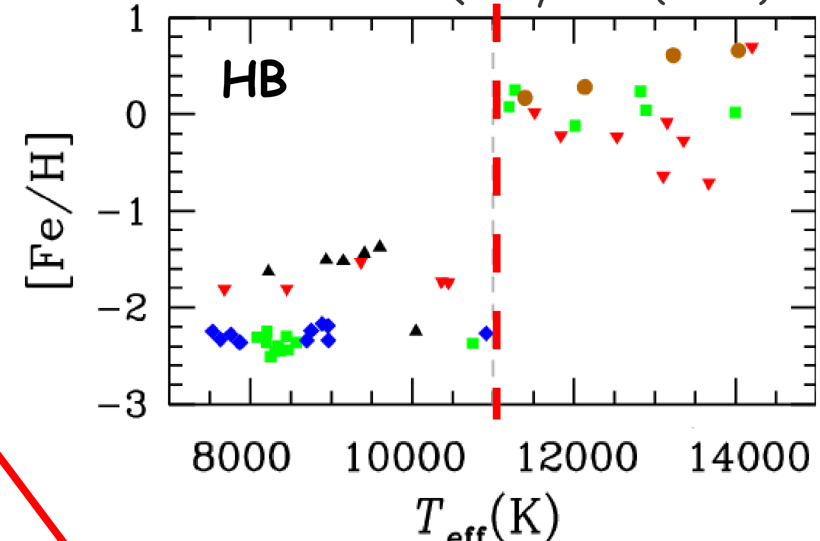
~ 8000 K

Radiative levitation !!

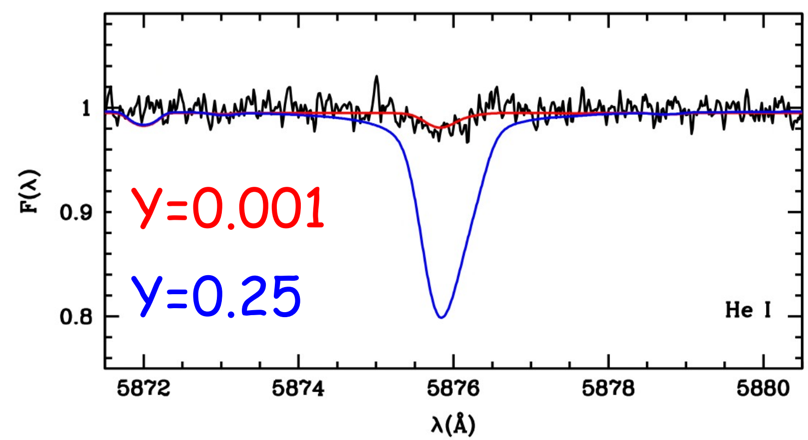
observed in HB stars

with Teff> 11000 K

Quievy et al.(2009)

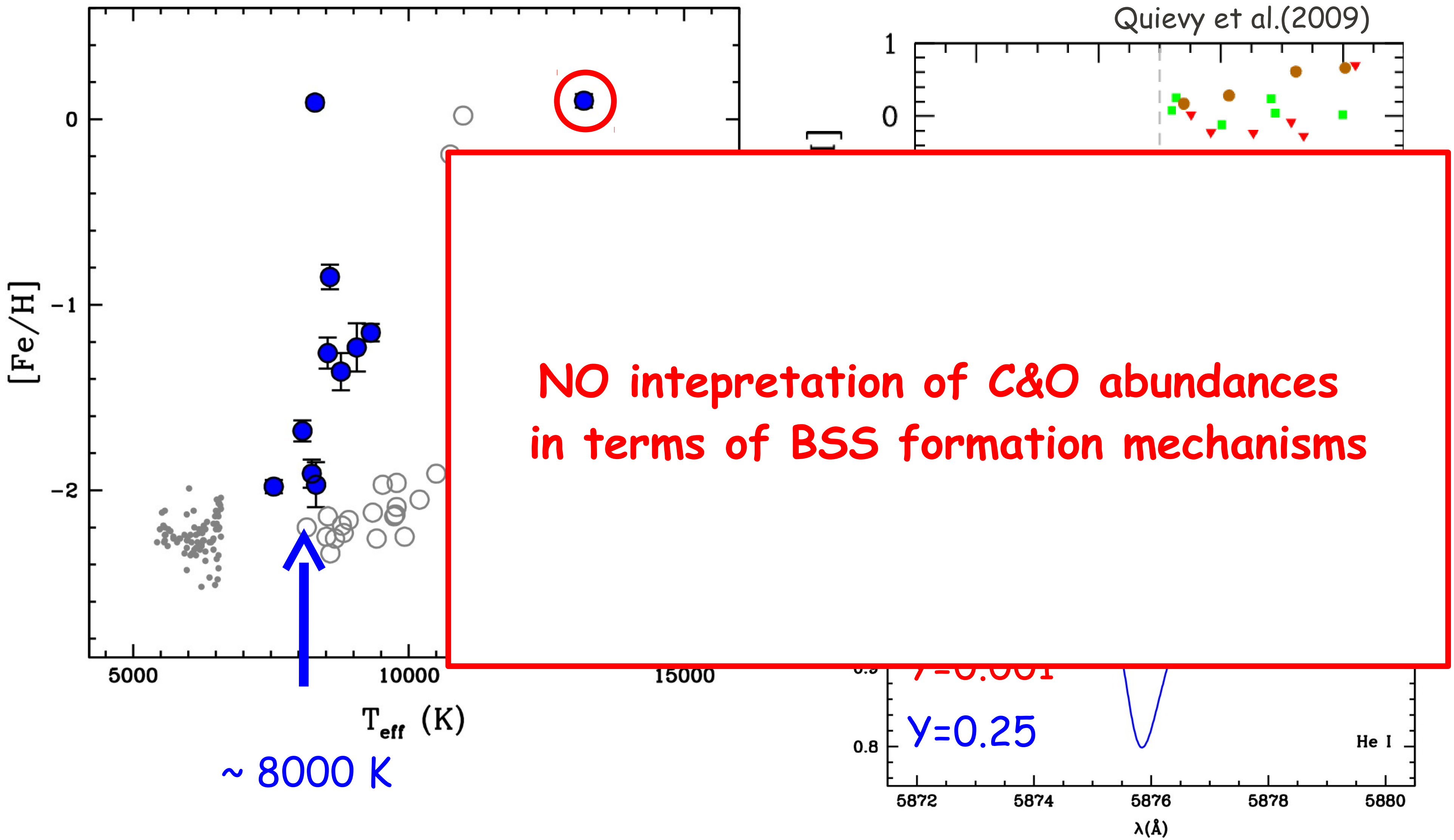


Gravitational settling of He

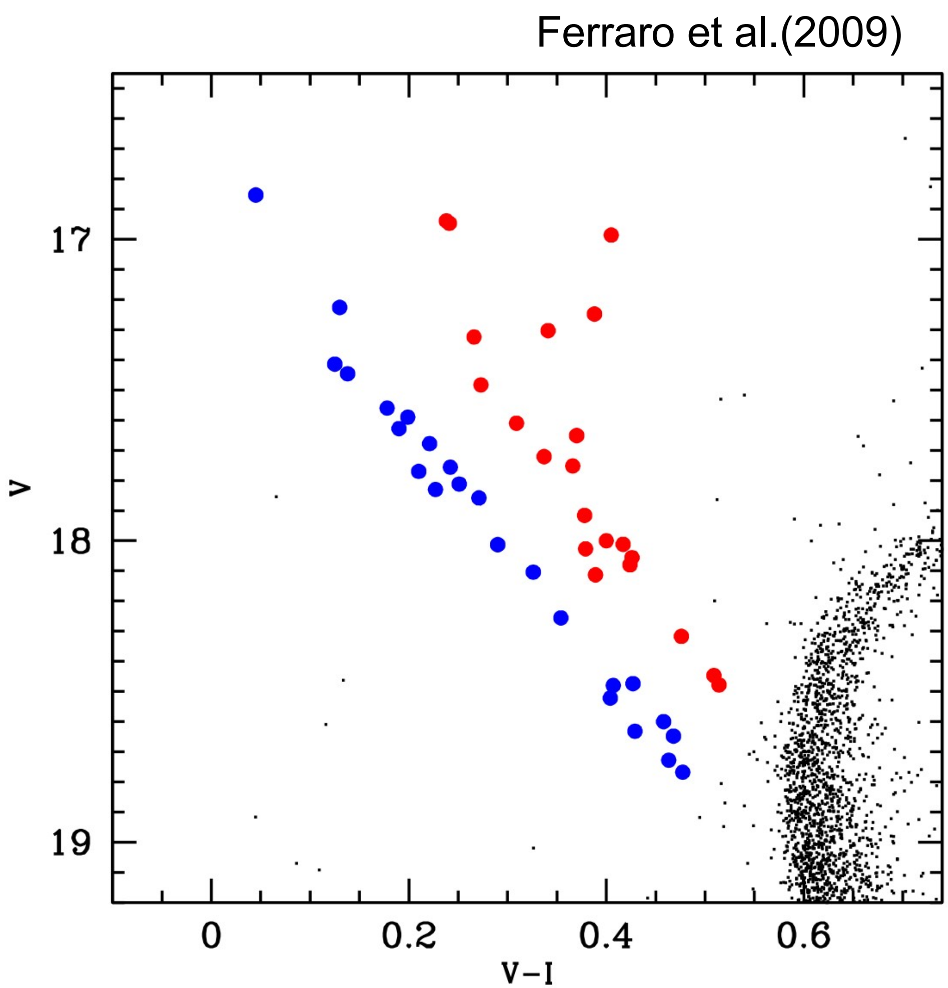


NGC 6397

Radiative levitation:
observed in HB stars
with Teff> 11000 K



M30



2 distinct sequences of BSS !!

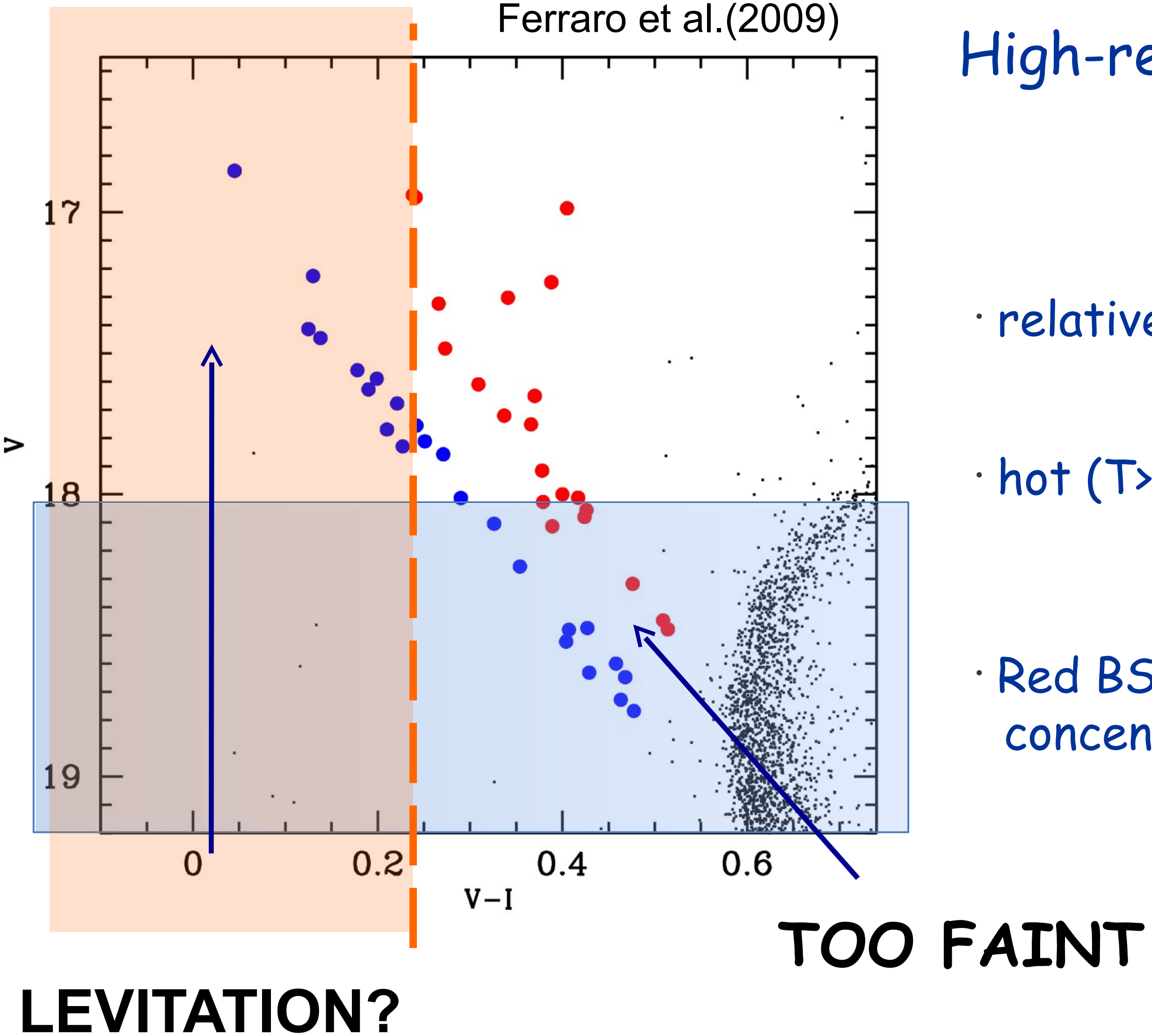
- Similarly populated
- Almost parallel

Blue BSS → collisional

Red BSS → mass transfer binaries

Cluster core-collapse occurred 1-2 Gyr ago and boosted BSS formation

M30

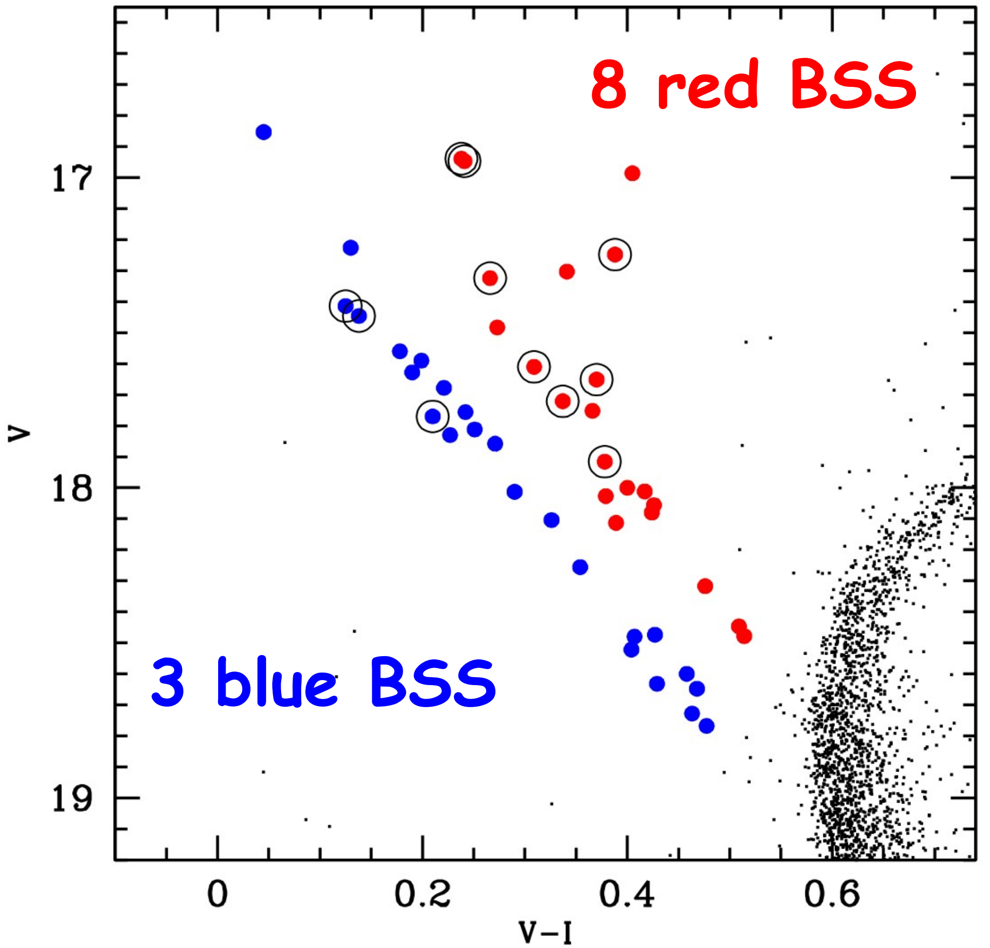


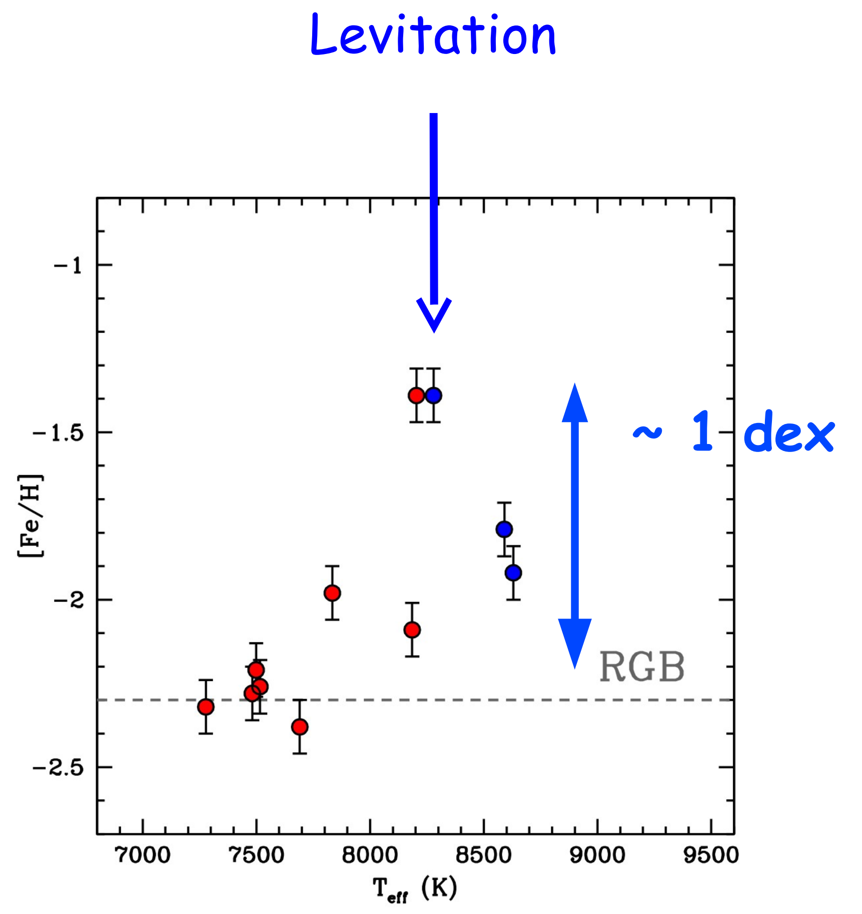
High-res spectra for these BSS…
a challenging task

- relatively faint
- hot (T>8000 K): levitation?
- Red BSS are centrally concentrated in the inner 30 arcsec

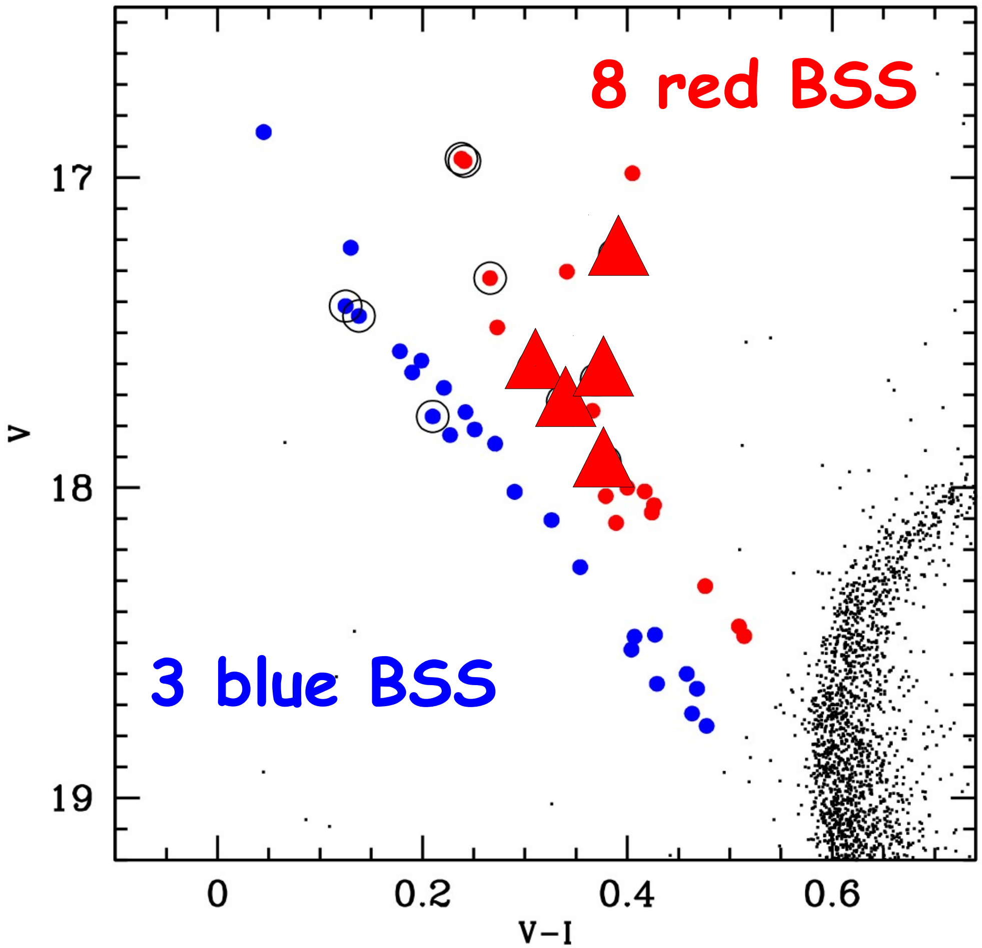
M30

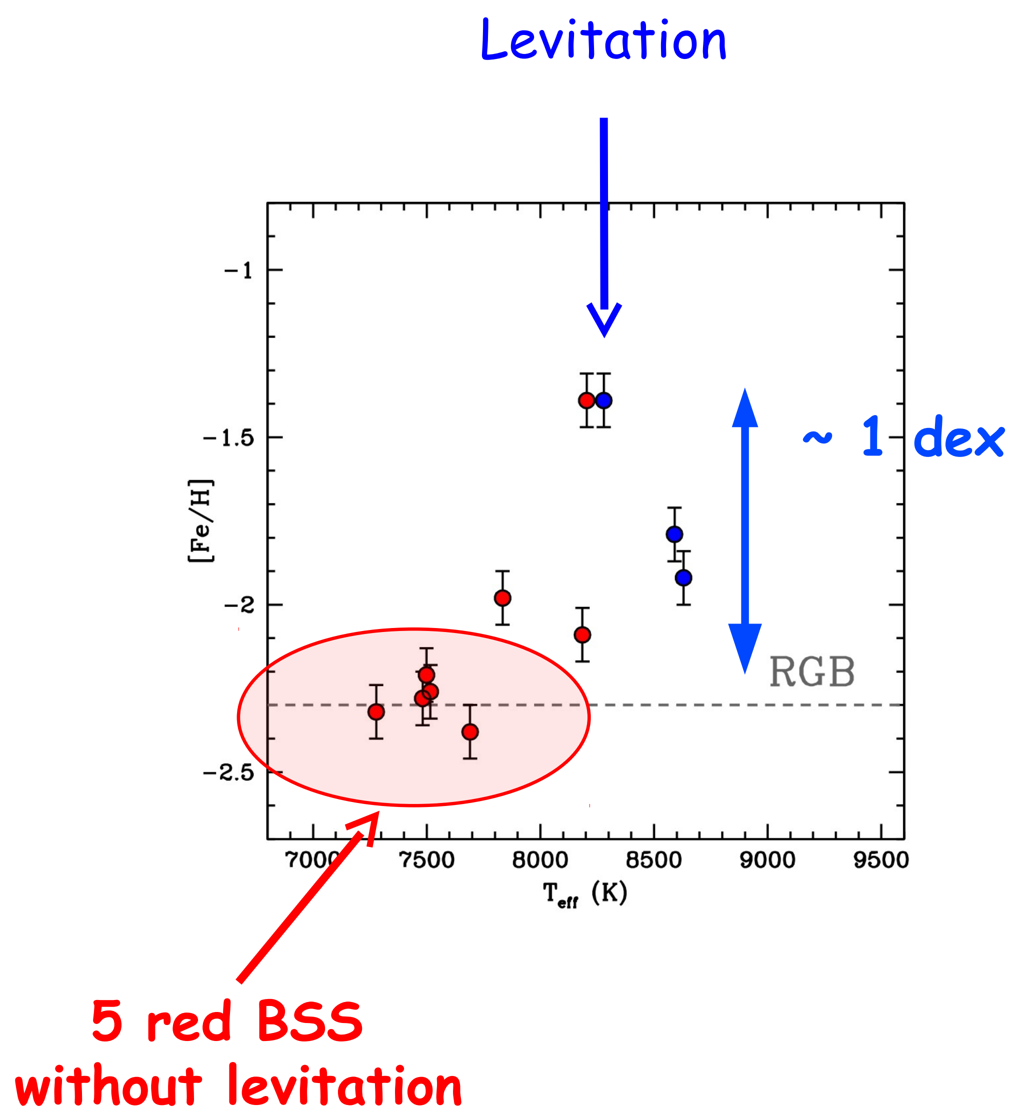
Chemical analysis for 11 BSS (Lovisi et al., 2013a)





M30


8 red BSS
3 blue BSS
17
18
19
V
0
0.2
0.4
0.6
V−I

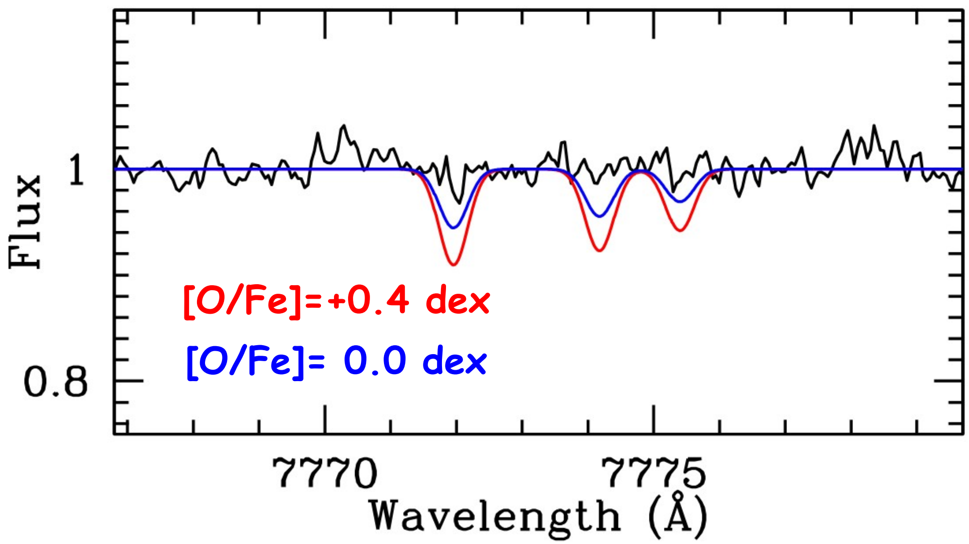

Levitation
~ 1 dex
RGB
−1
−1.5
−2
−2.5
[Fe/H]
7000
7500
8000
8500
9000
9500
T_{eff} (K)
5 red BSS
without levitation

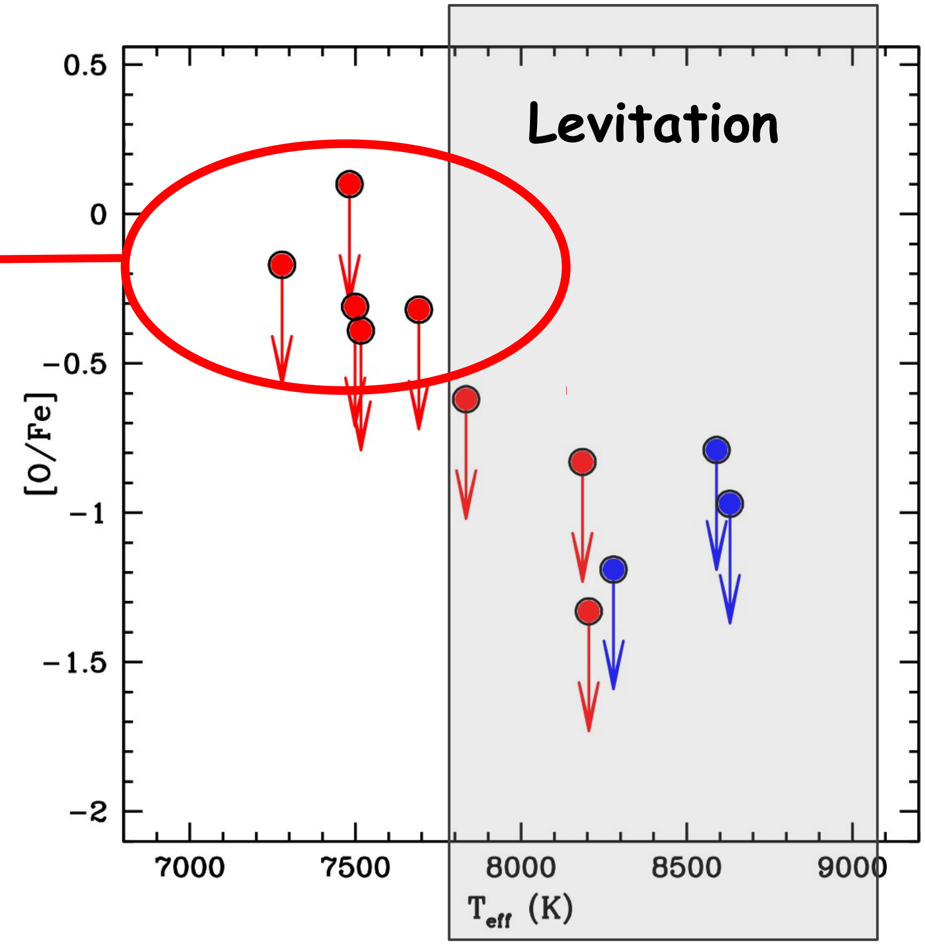
M30

Oxygen abundance: only upper limits but …

No Levitation:

4 red BSS with subsolar [O/Fe]

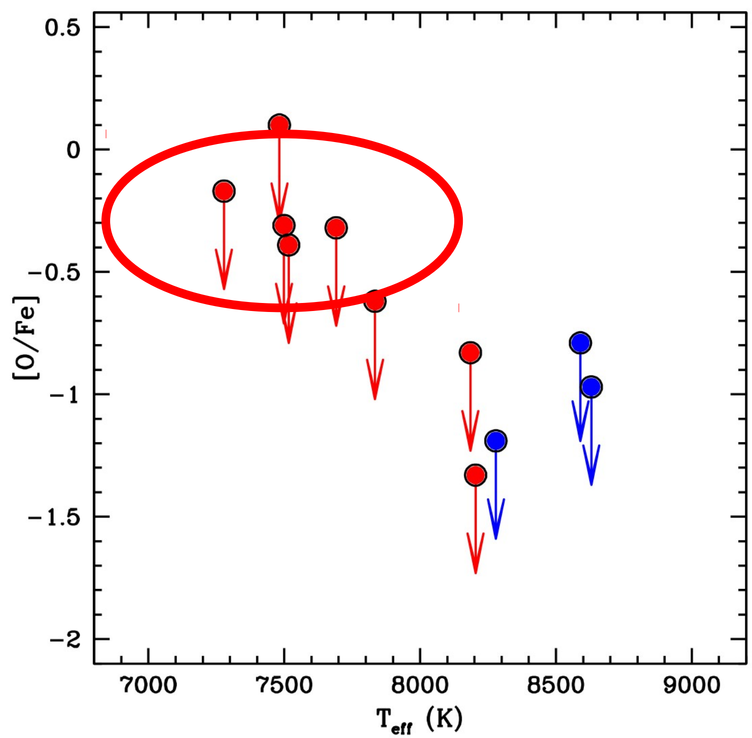




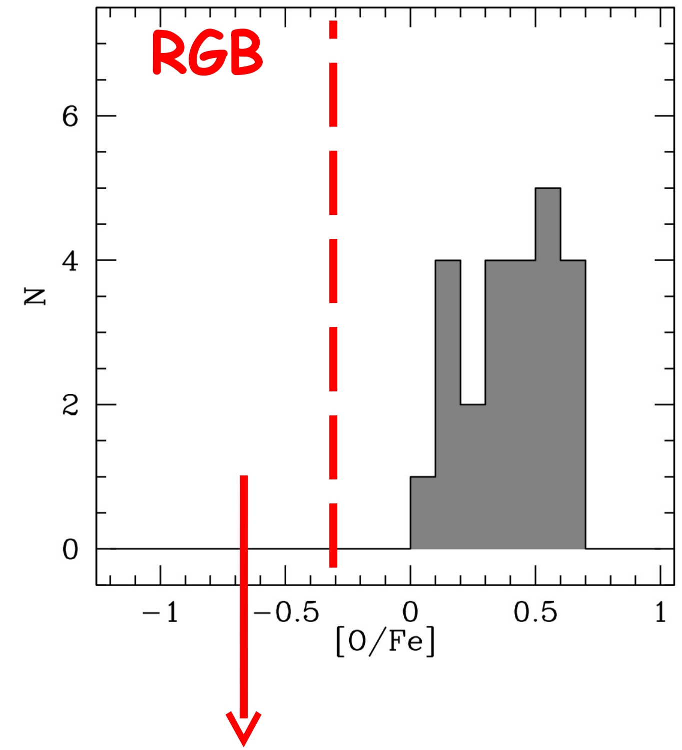
M30

Red BSS: [O/Fe] < -0.3 dex

(No information about C)



Carretta et al.(2010)

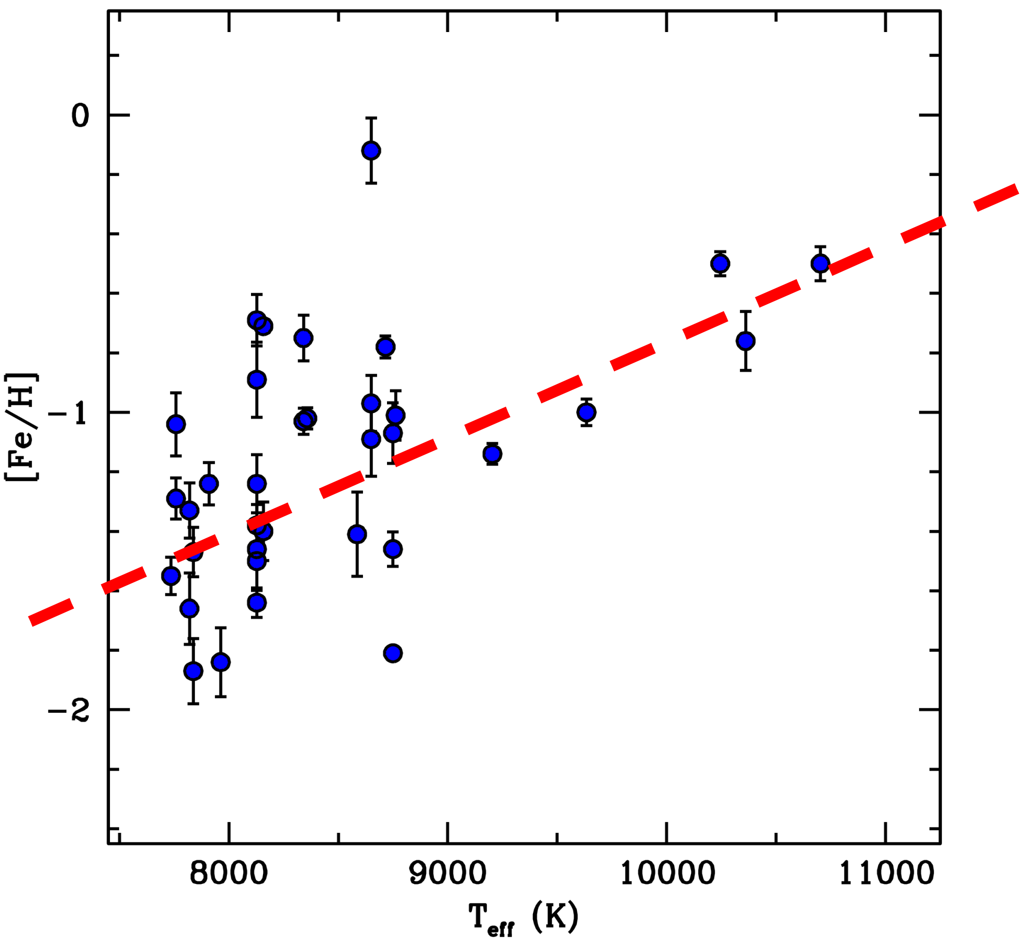


Hint of mass transfer in the red BSS

Incompatible with the [O/Fe] distribution of the cluster

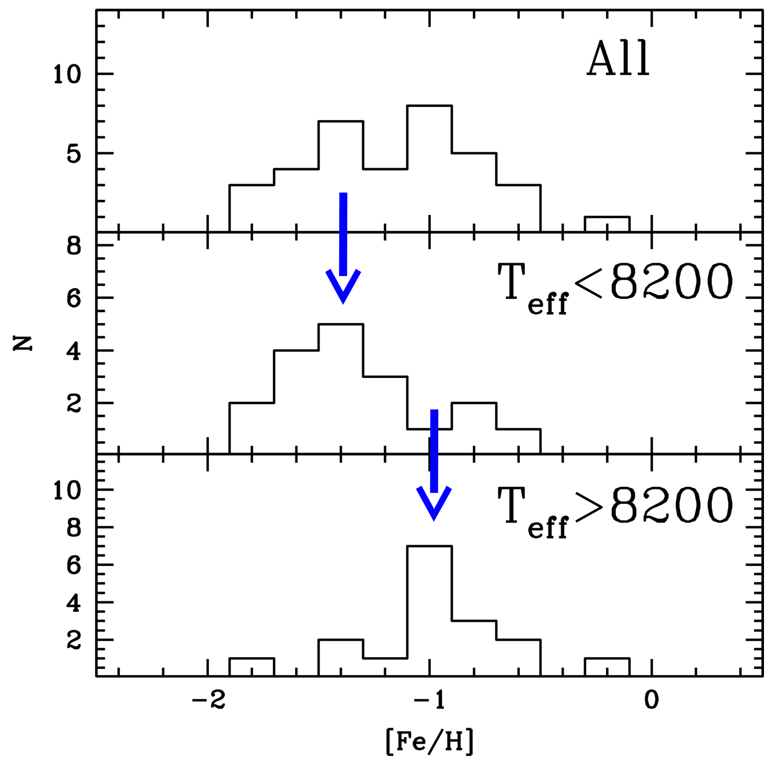
Omega *Cen*

Chemical analysis for 43 BSS
(Mucciarelli et al., in prep.)

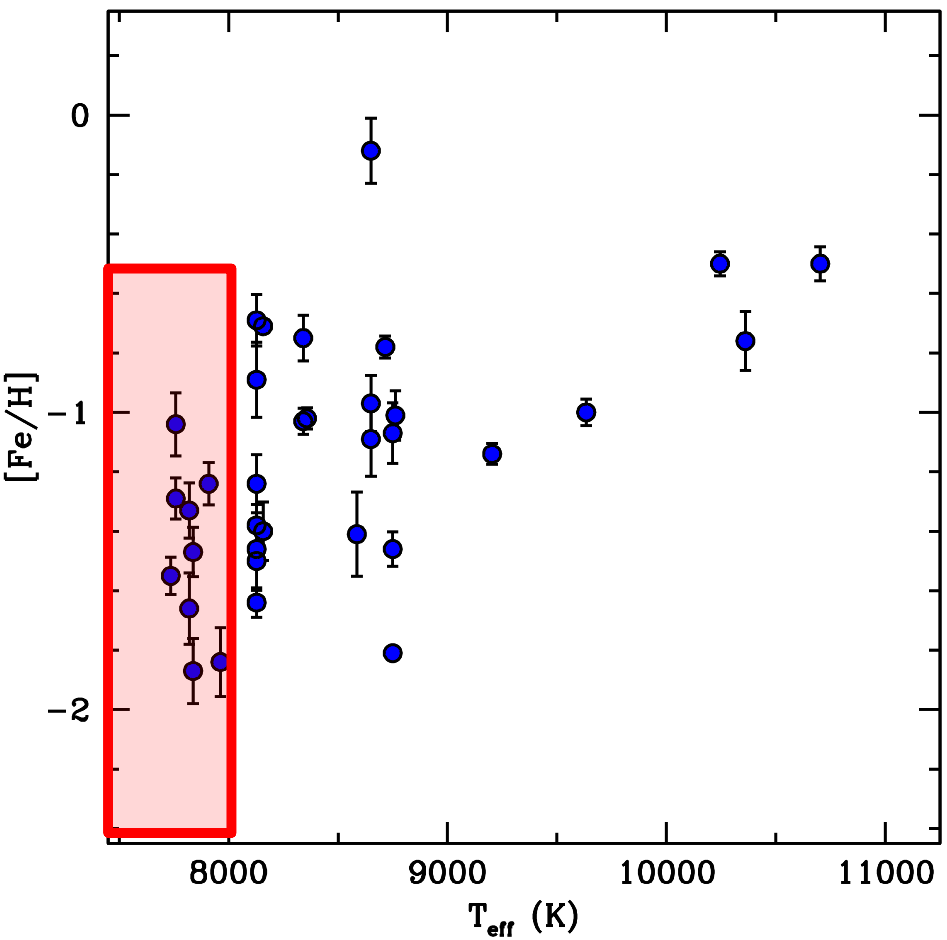


[Fe/H] increases increasing Teff

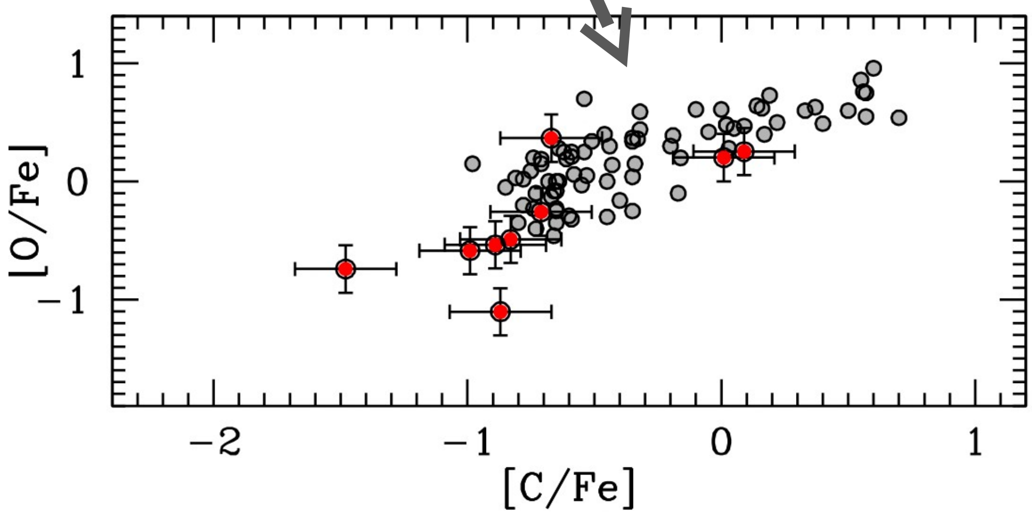
Radiative Levitation



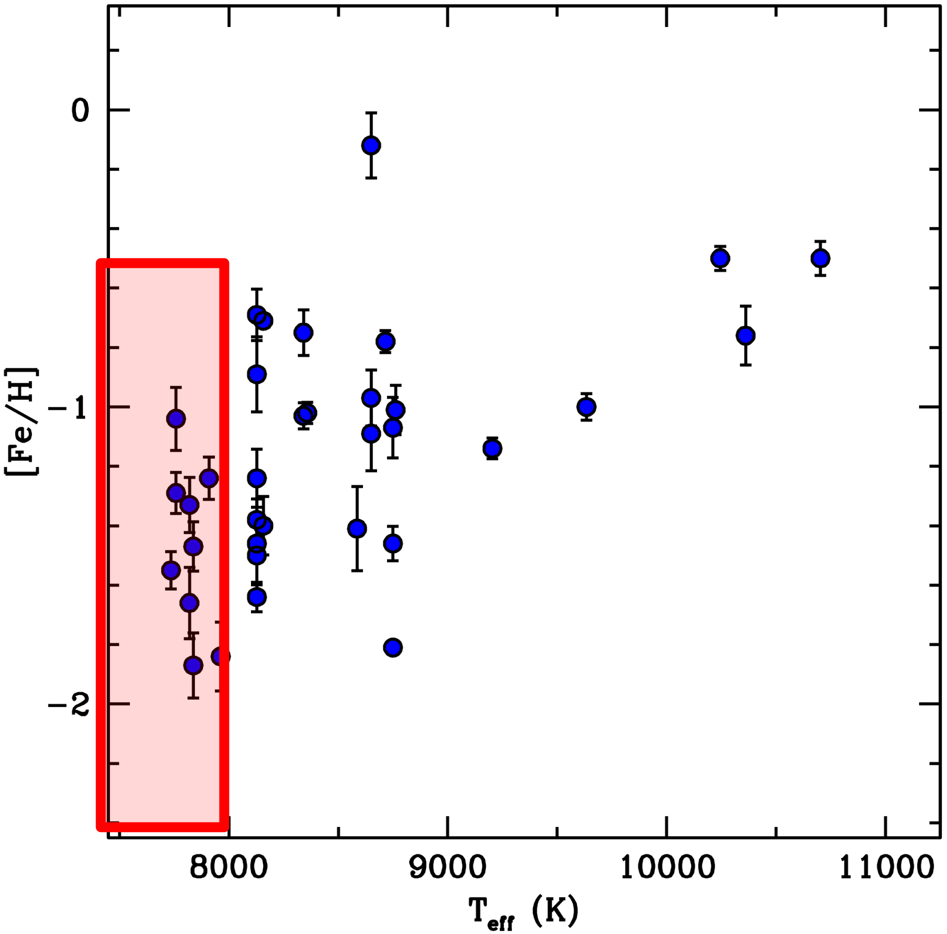
Omega *Cen*



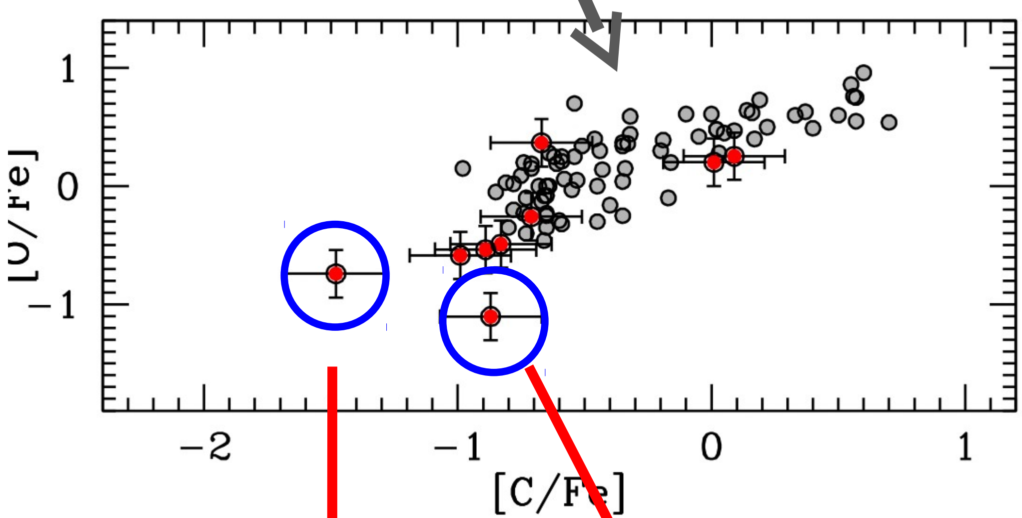
Marino et al.2012



Omega *Cen*



Marino et al.2012



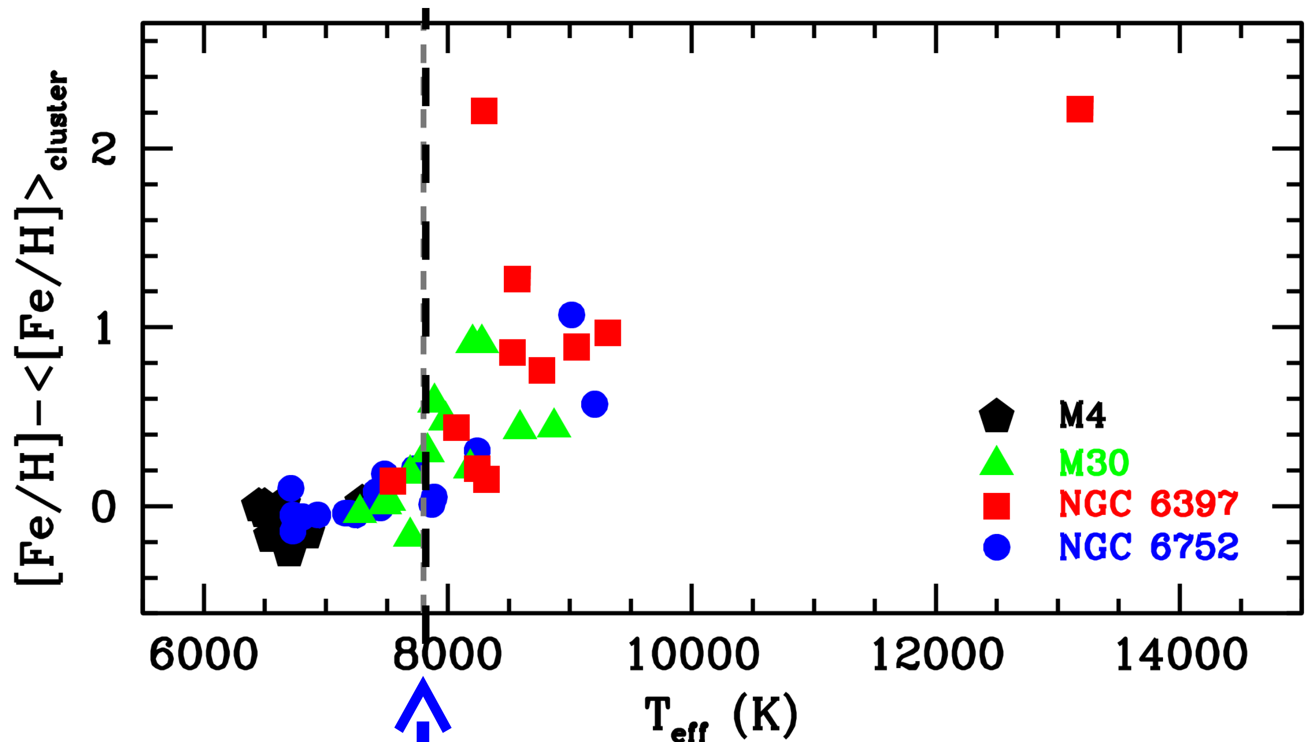
C-poor BSS

O-poor BSS

Hint of mass transfer

Conclusion (1)

Radiative levitation



First evidence of radiative levitation in BSS

~ 8000 K

Levitation occurrs in BSS hotter than ~8000 K

Conclusion (2)

CO-depletion

1) CO-depletion signature of MT

Cluster	#star	#C,O-depl	%
M30 (red)	**5**	**4**	**80**
47 Tuc	43	6	14
Omega Cen	9	1-2	11-22
M4	11	0	0
NGC 6752	15	0	0
NGC 6397	-	-	-

Conclusion (2)

CO-depletion

1) CO-depletion signature of MT

2) Depletion is probably a transient phenomenon

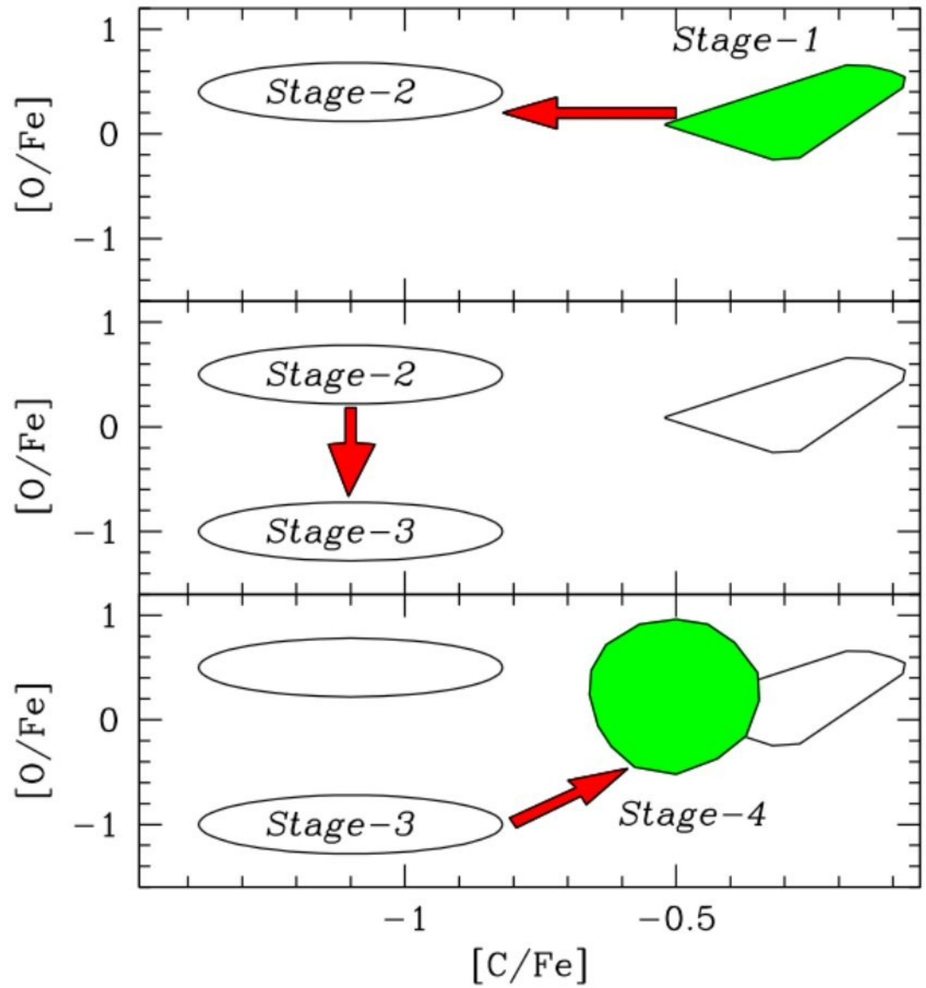
Cluster	#star	#C,O-depl	%
M30 (red)	5	4	80
47 Tuc	**43**	**6**	**14**
Omega Cen	**9**	**1-2**	**11-22**
M4	**11**	**0**	**0**
NGC 6752	**15**	**0**	**0**
NGC 6397	-	-	-

Conclusion (2)

CO-depletion

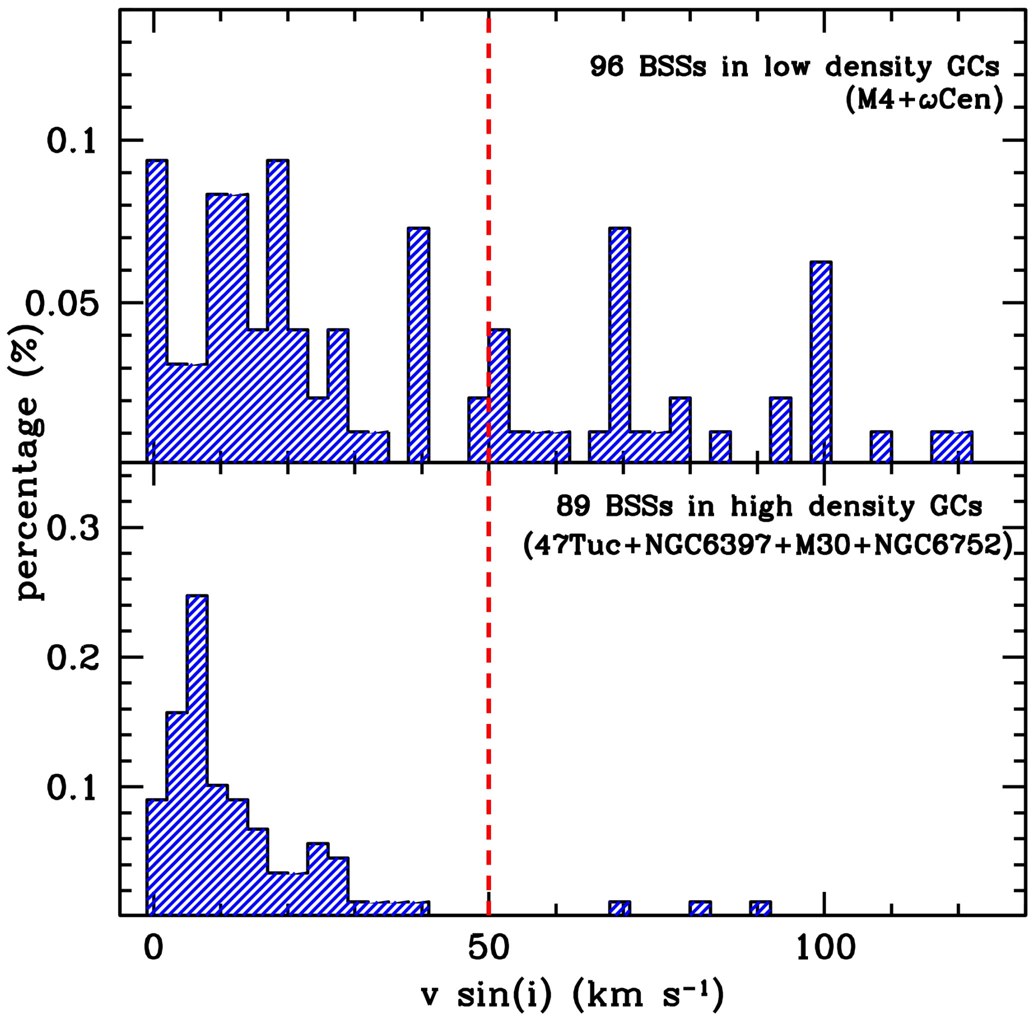
1) CO-depletion signature of MT

2) Depletion is probably a transient phenomenon



Mixing might restore the original abundances

Rotational velocities



BSS essentially slow rotators

Wide range of values

Possible link with cluster density

Cosmic-Lab

Visit our web-site: **www.cosmic-lab.eu**

Thank you