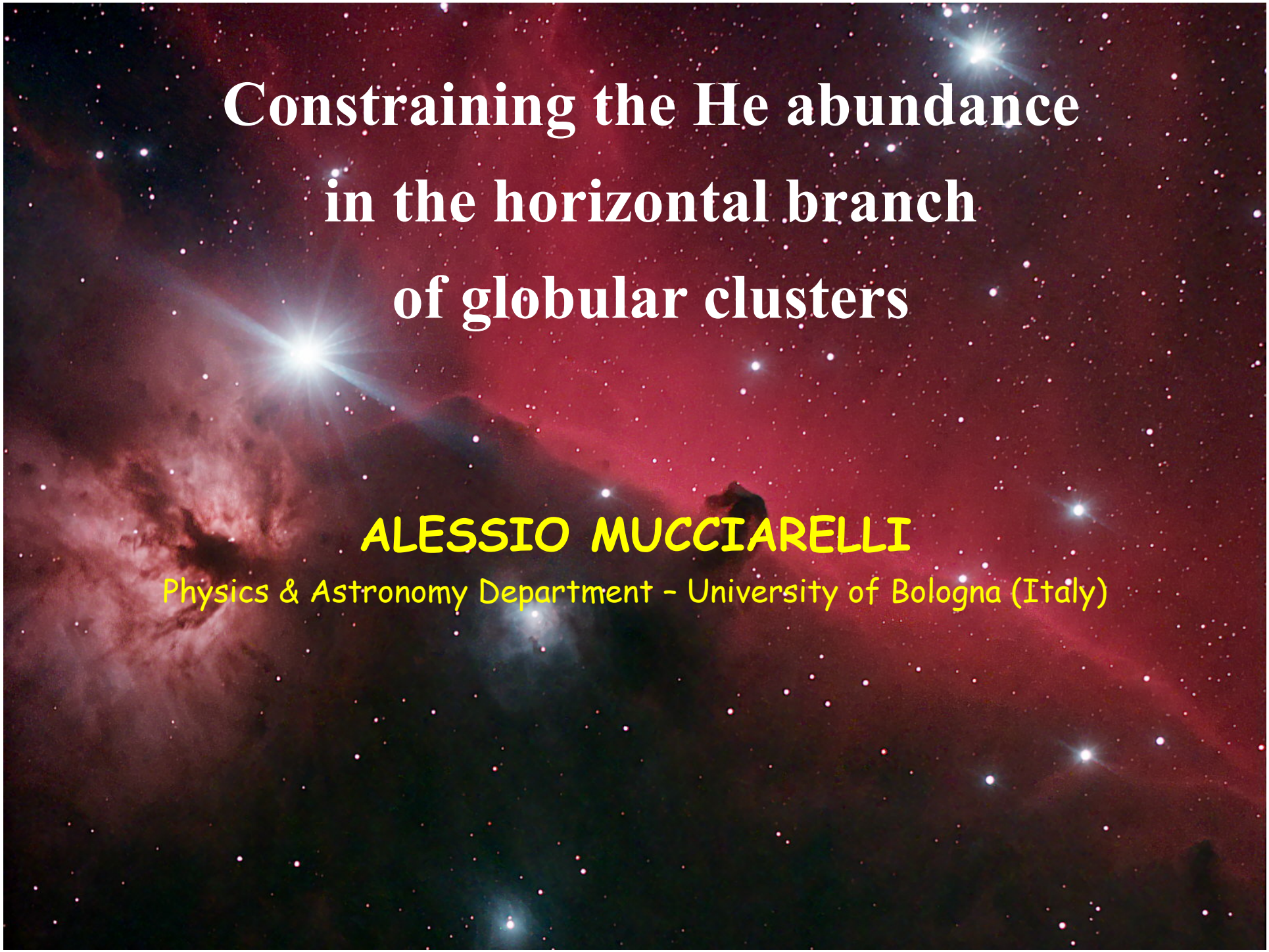


Constraining the He abundance in the horizontal branch of globular clusters

ALESSIO MUCCIARELLI

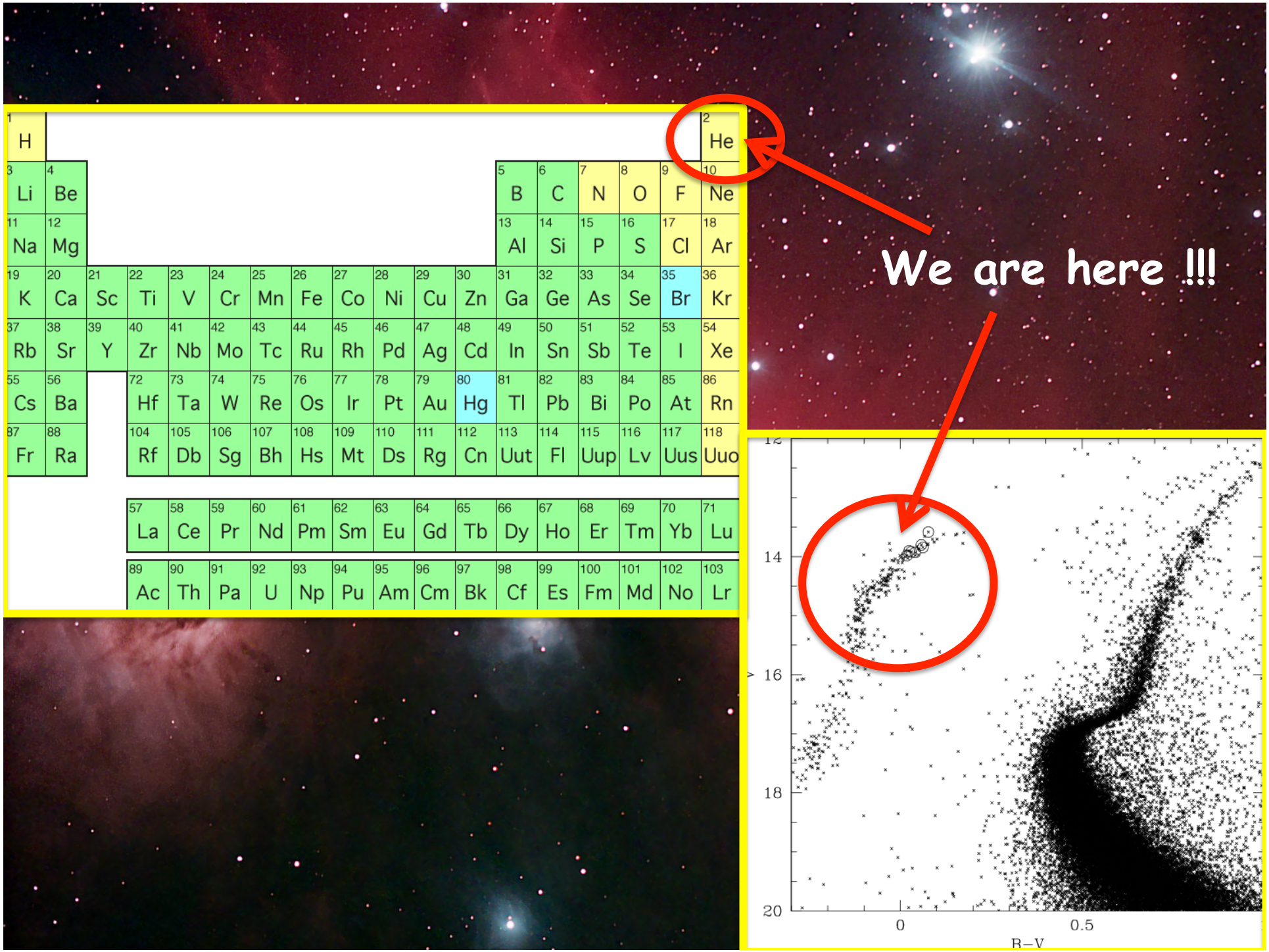
Physics & Astronomy Department – University of Bologna (Italy)

Cosmic-Lab

- 5-year project
- *Advanced Research Grant* funded by the European Research Council (ERC)
- PI: Francesco R. Ferraro (Dip. of Physics & Astronomy – Bologna University)
- 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

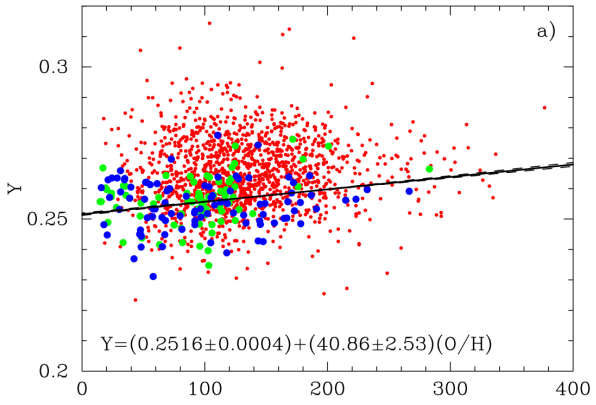
} as probe-particles

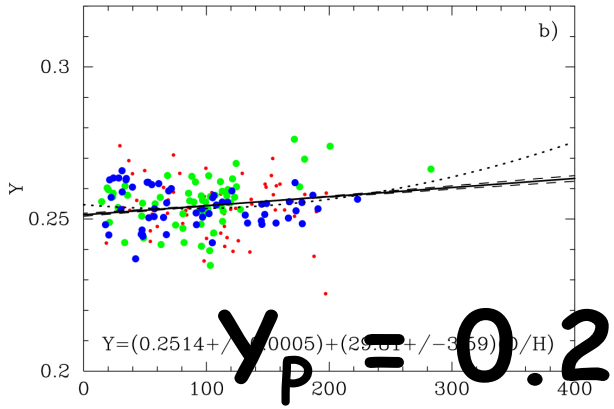

1 H
2 He
3 Li
4 Be
5 B
6 C
7 N
8 O
9 F
10 Ne
11 Na
12 Mg
13 Al
14 Si
15 P
16 S
17 Cl
18 Ar
19 K
20 Ca
21 Sc
22 Ti
23 V
24 Cr
25 Mn
26 Fe
27 Co
28 Ni
29 Cu
30 Zn
31 Ga
32 Ge
33 As
34 Se
35 Br
36 Kr
37 Rb
38 Sr
39 Y
40 Zr
41 Nb
42 Mo
43 Tc
44 Ru
45 Rh
46 Pd
47 Ag
48 Cd
49 In
50 Sn
51 Sb
52 Te
53 I
54 Xe
55 Cs
56 Ba
72 Hf
73 Ta
74 W
75 Re
76 Os
77 Ir
78 Pt
79 Au
80 Hg
81 Tl
82 Pb
83 Bi
84 Po
85 At
86 Rn
87 Fr
88 Ra
104 Rf
105 Db
106 Sg
107 Bh
108 Hs
109 Mt
110 Ds
111 Rg
112 Cn
113 Uut
114 Fl
115 Uup
116 Lv
117 Uus
118 Uuo
57 La
58 Ce
59 Pr
60 Nd
61 Pm
62 Sm
63 Eu
64 Gd
65 Tb
66 Dy
67 Ho
68 Er
69 Tm
70 Yb
71 Lu
89 Ac
90 Th
91 Pa
92 U
93 Np
94 Pu
95 Am
96 Cm
97 Bk
98 Cf
99 Es
100 Fm
101 Md
102 No
103 Lr
We are here !!!
14
16
18
20
0
0.5
B−V

Setting the stage – measuring primordial Y

SBBN Y = 0.2477±0.0001 (Ade+13)

Izotov+13

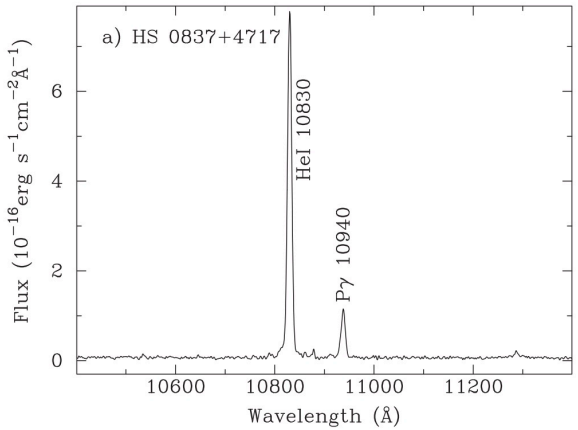


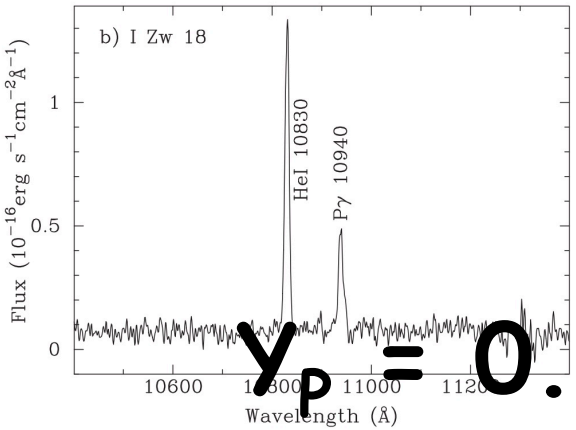


HII regions

$Y_P = 0.254 \pm 0.003$

Izotov+14

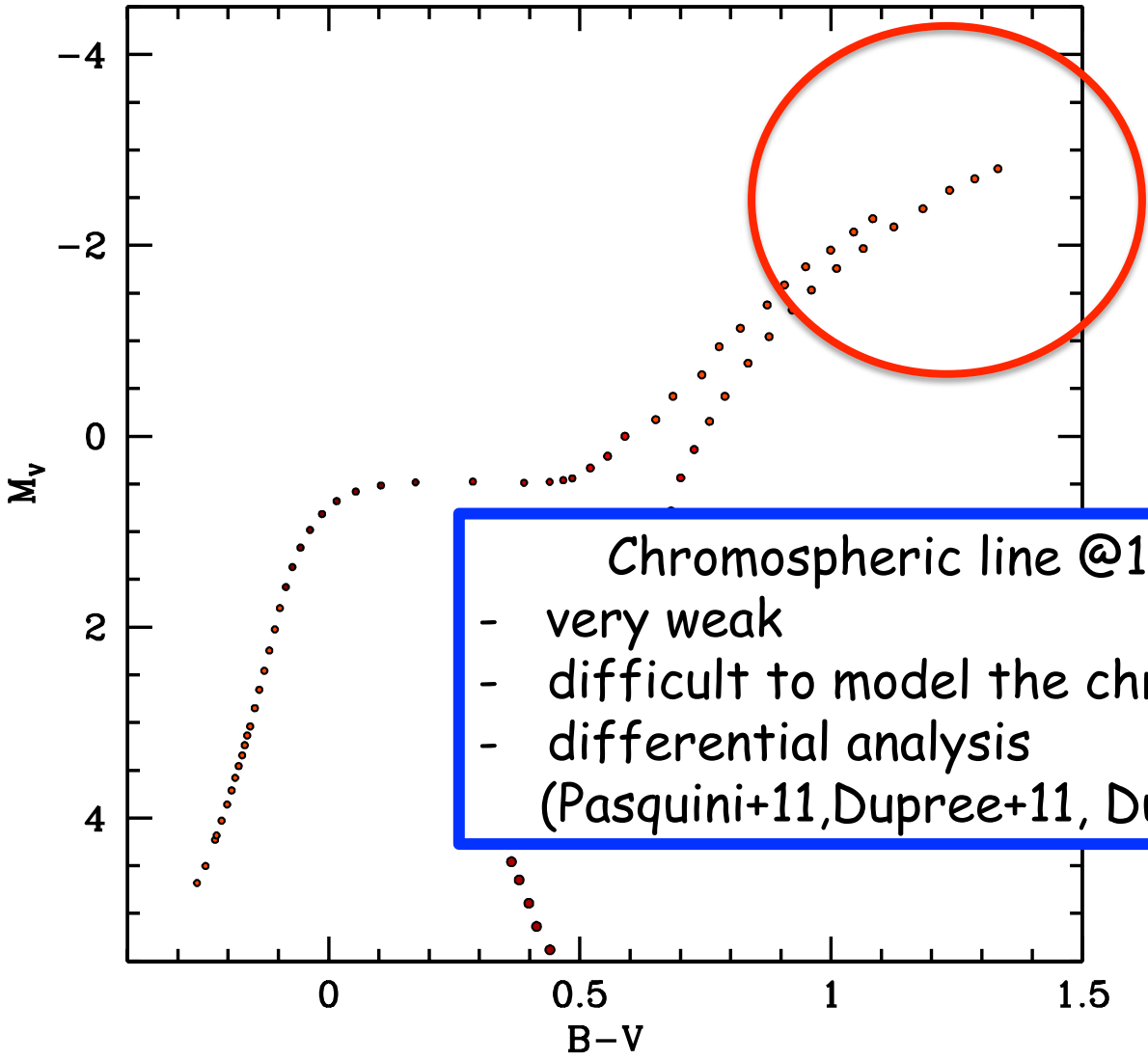




HII regions

$Y_P = 0.255 \pm 0.002$

Where we can measure He in GCs ?

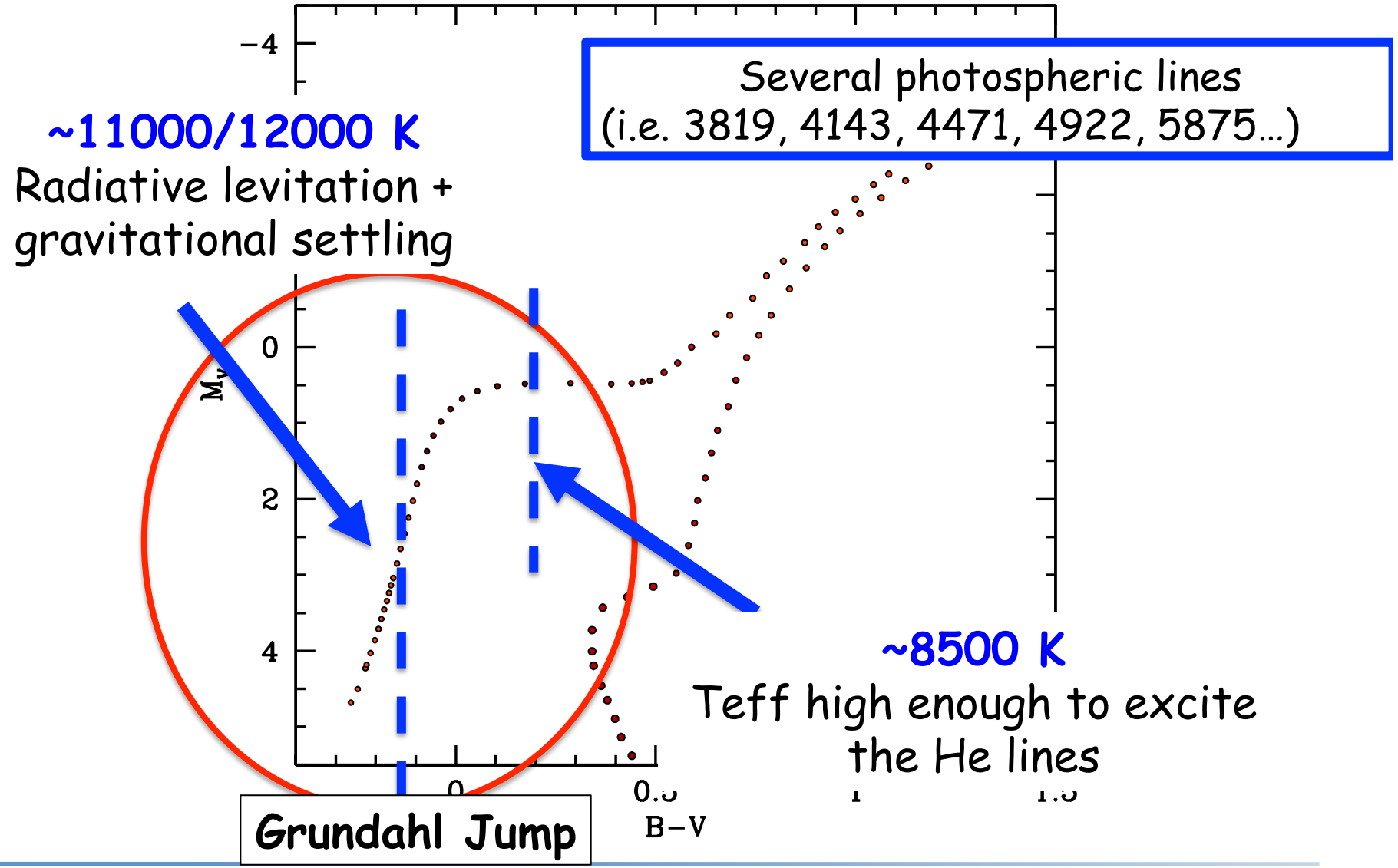


Chromospheric line @10830 A

- very weak
- difficult to model the chromosphere
- differential analysis

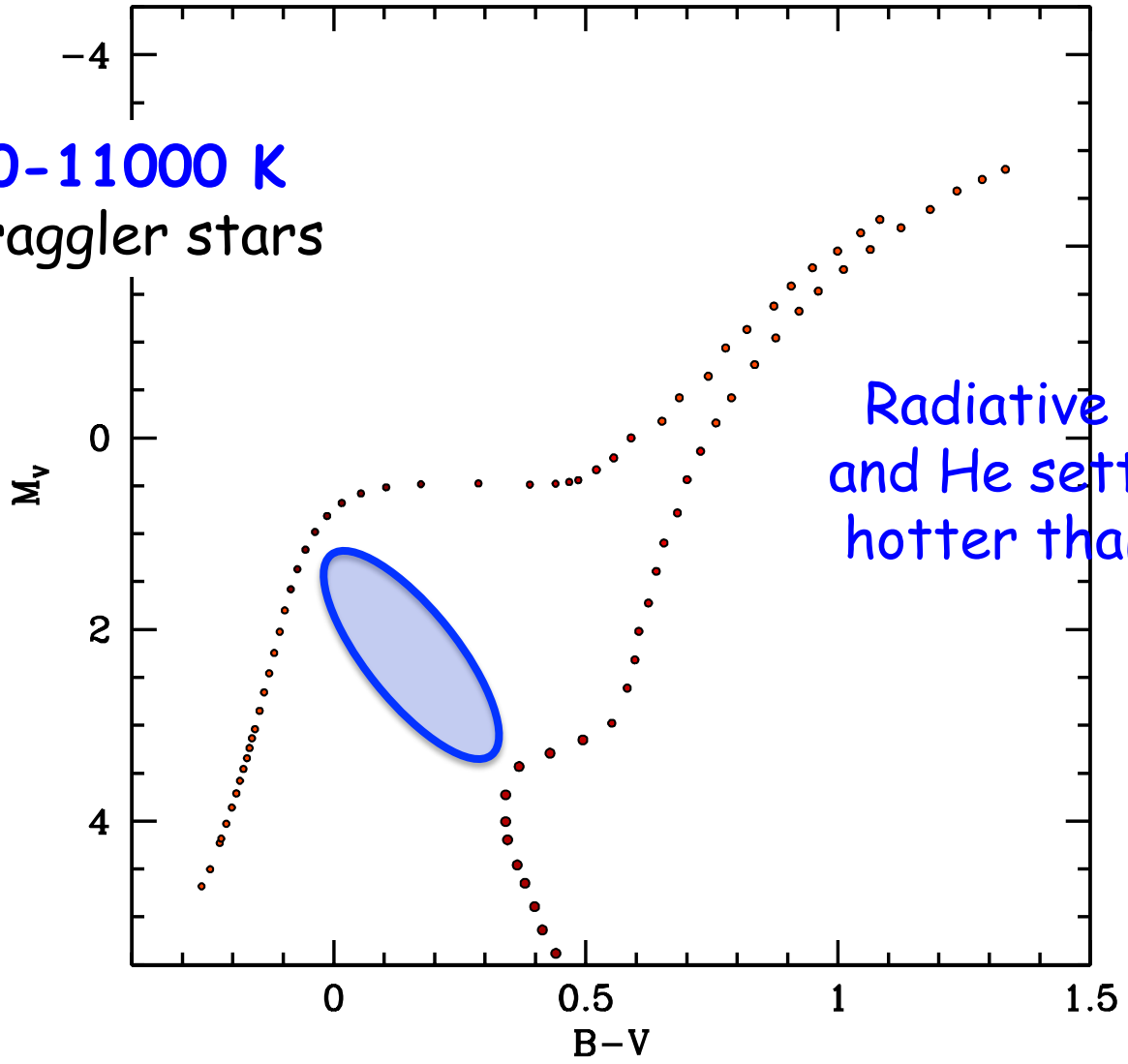
(Pasquini+11,Dupree+11, Dupree+13)

Where we can measure He in GCs ?



Where we can measure He in GCs ?

~ 7000-11000 K
Blue Straggler stars

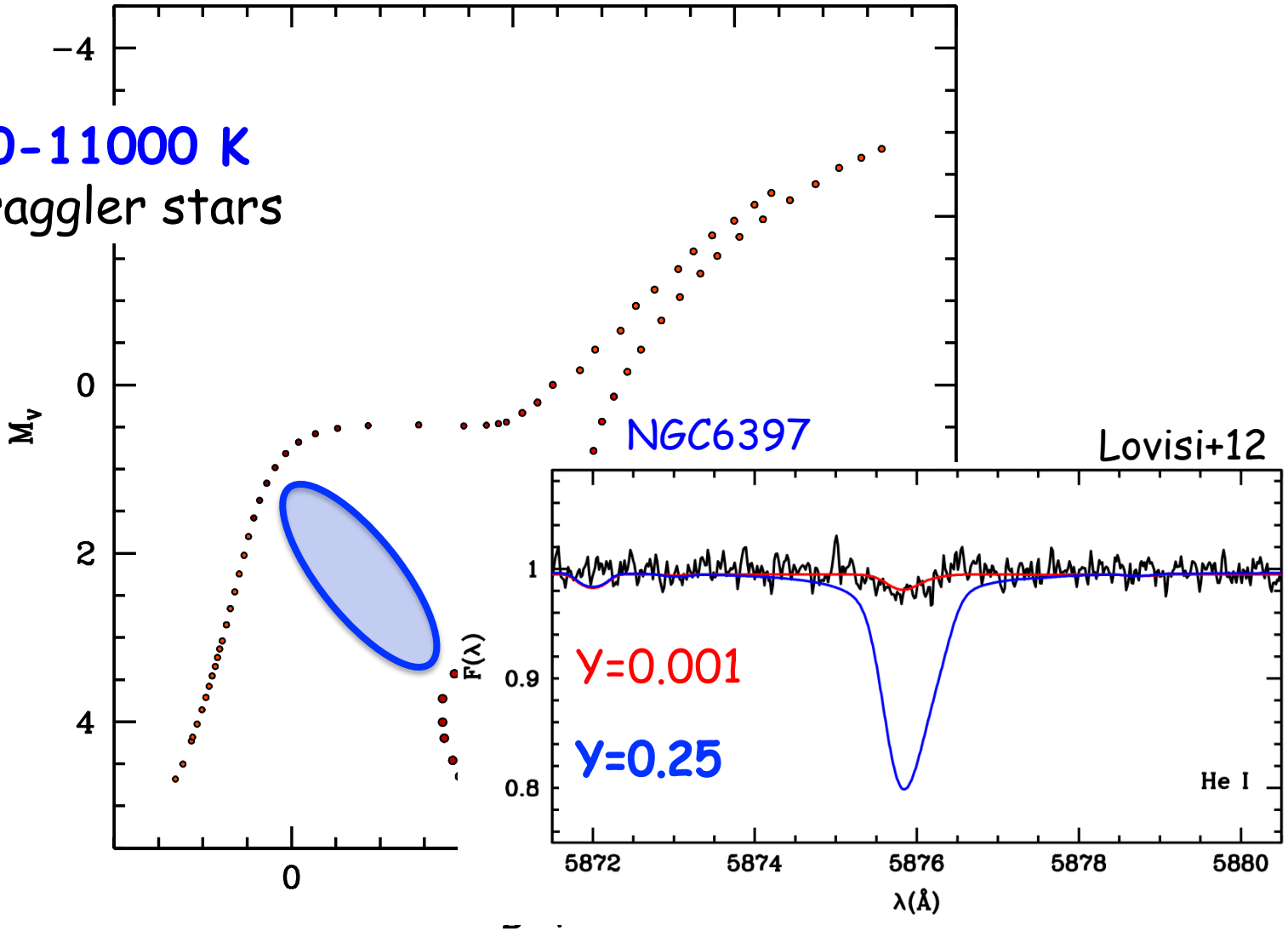


Radiative levitation
and He settling in BSS
hotter than ~8000 K

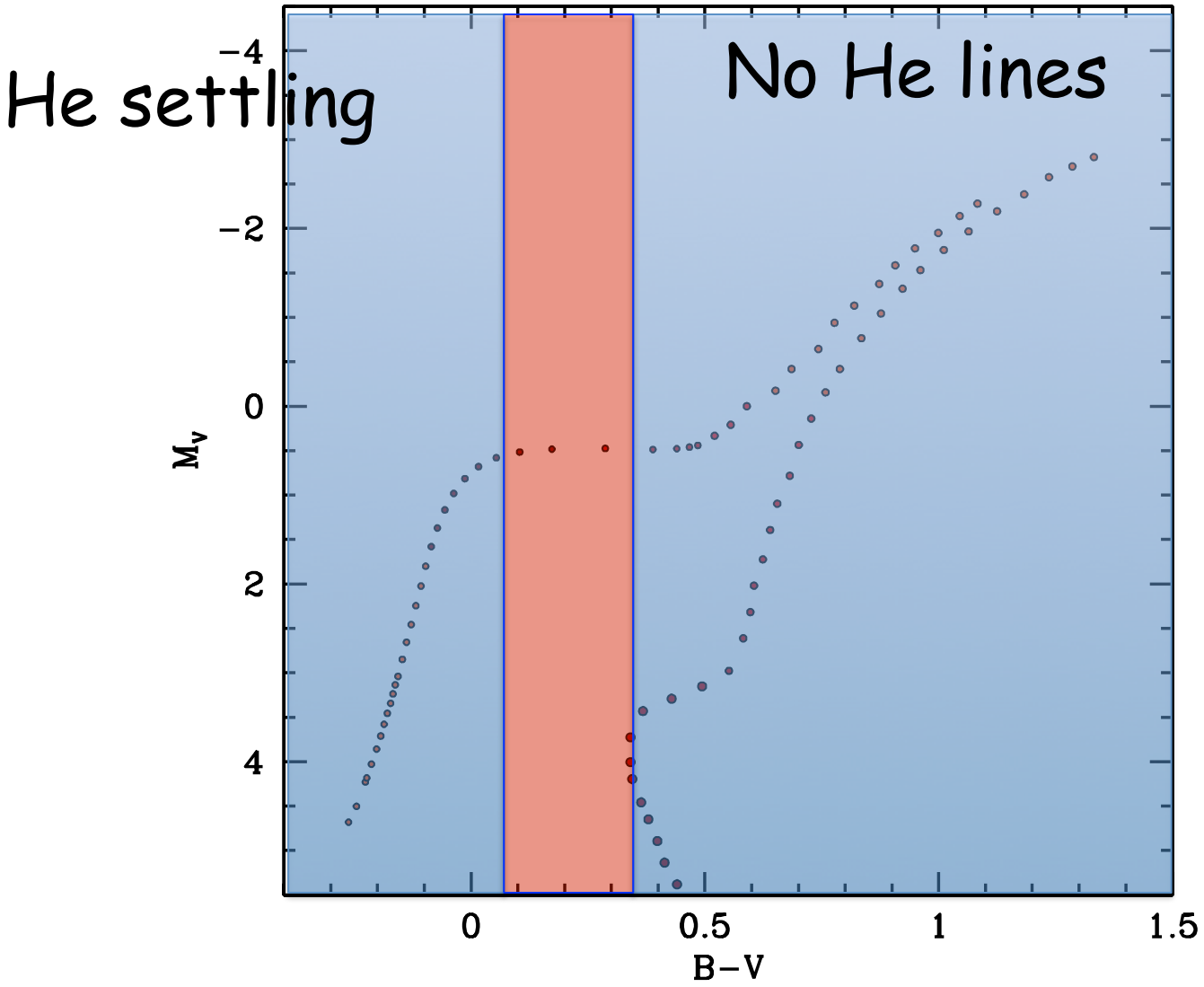
Where we can measure He in GCs ?

~ 7000-11000 K

Blue Straggler stars

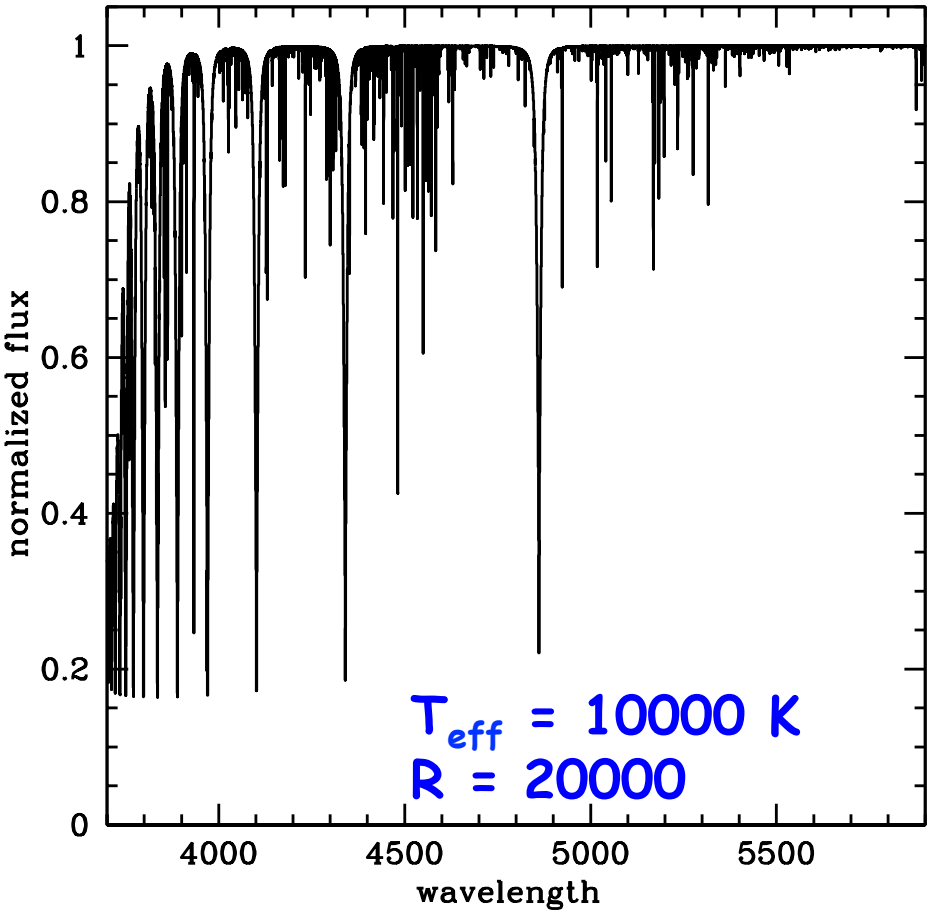


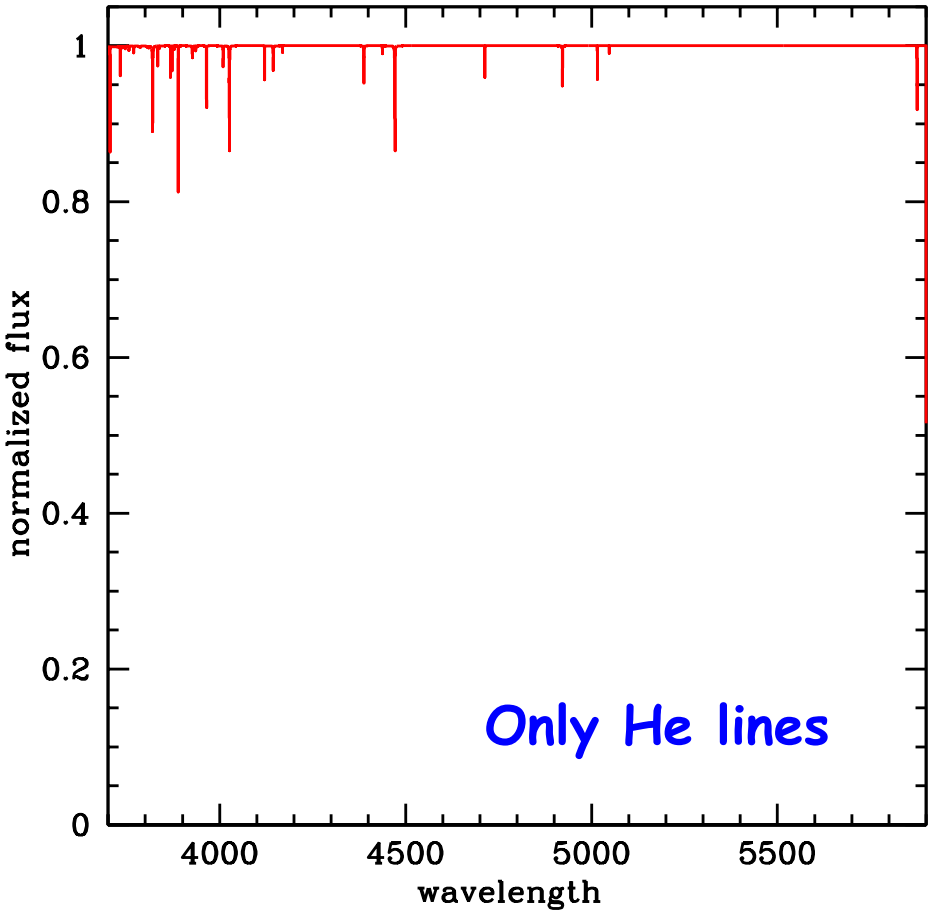
Where we can measure He in GCs ?



The main difficulties in measuring He

Basic requirements
(1) SNR > 100 to obtain an internal uncertainty smaller than 0.01
(2) High resolution (R > 15000)
(3) Accurate photometry to derive the parameters





The main difficulties in measuring He

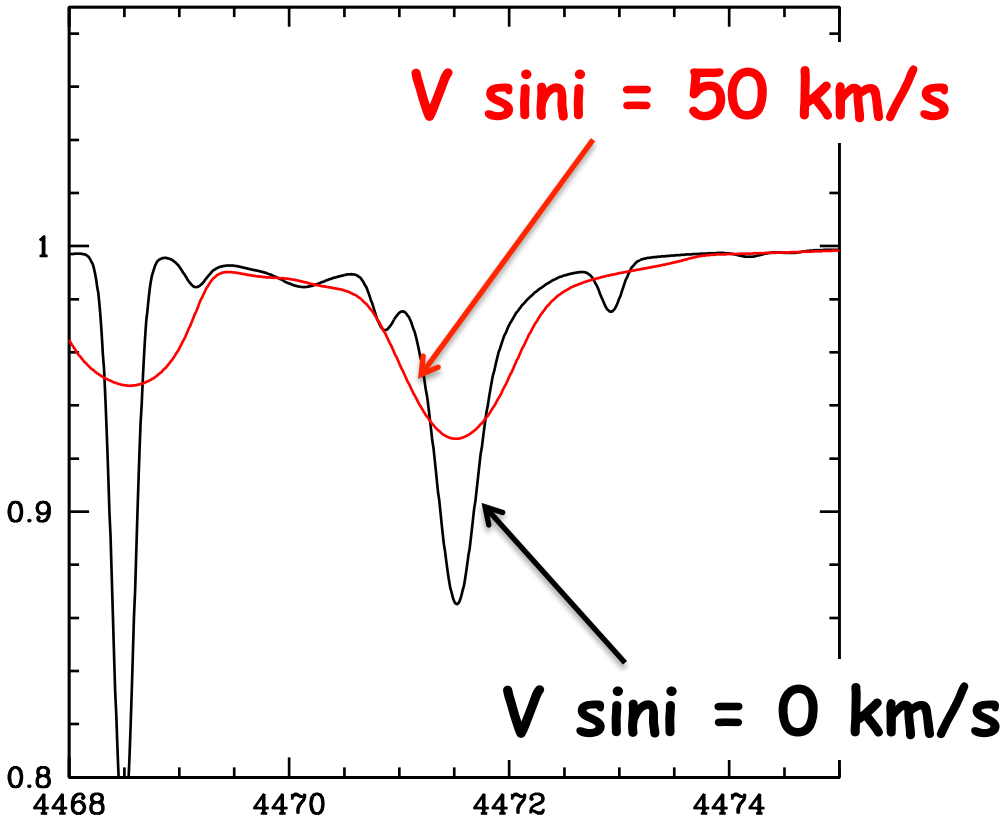
Basic requirements
(1) SNR > 100 to obtain an internal uncertainty smaller than 0.01 dex
(2) High resolution (R > 15000)
(3) Accurate photometry to derive the parameters

δT_{eff} = 200 K → $\delta Y \sim 0.04$
$\delta \log g$ = 0.1 → $\delta Y \sim 0.01$
Other parameters (v_{turb}, vsini) are negligible

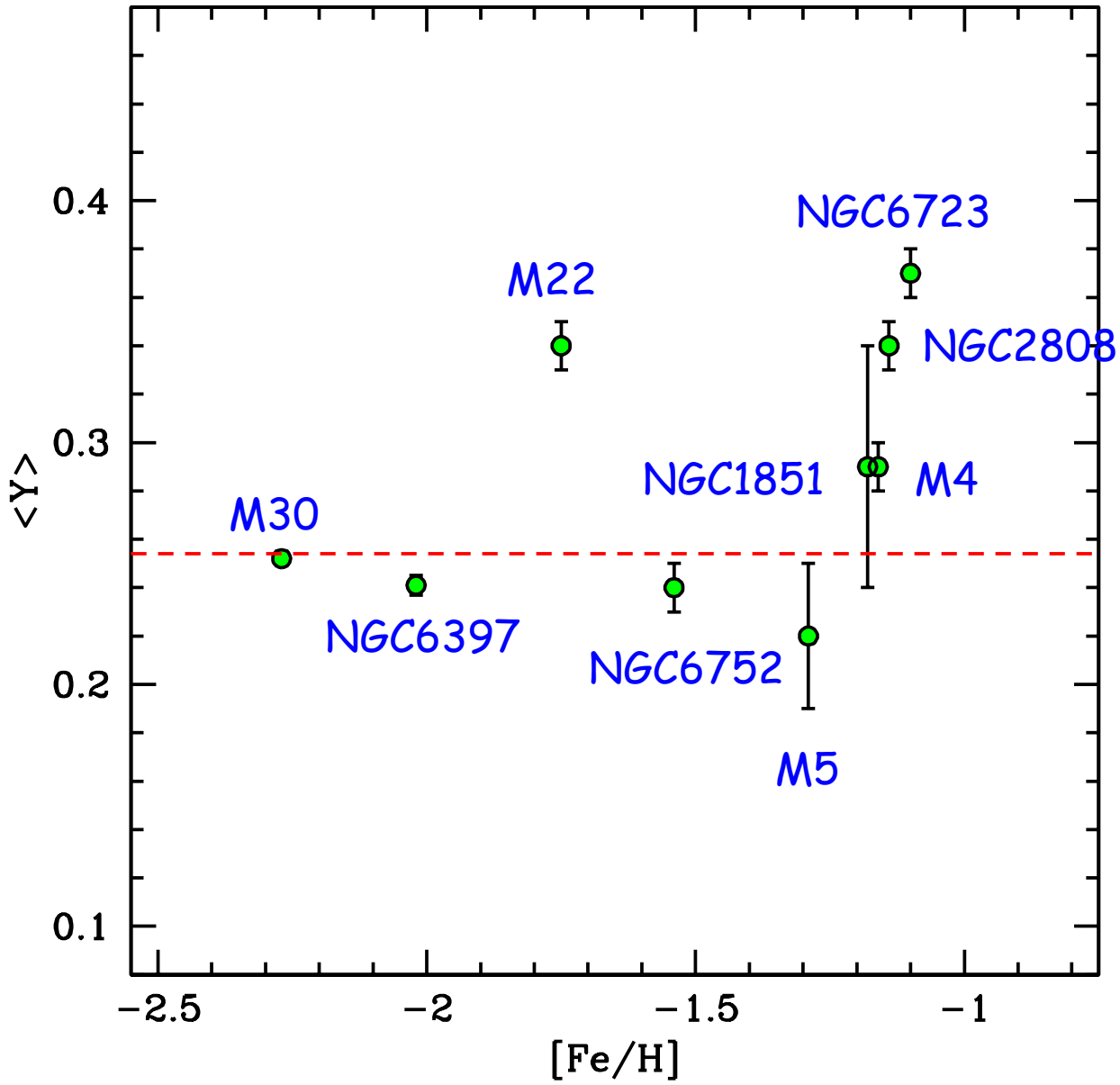
Methods to derive T_{eff} and logg
- Theoretical ZAHBs
- Color-T_{eff} relations (you need precise photometry)
- Spectroscopic methods (see Villanova+09,+12) , but dangerous (a few Fe lines)

The main difficulties in measuring He

Other issues:
(1) NLTE corrections (depend on the line and the parameters)
(2) The HB stars between 9000-12000 K can be fast rotators (up to 50 km/s)



He in GC HB stars: a summary



He in GC HB stars: a summary

NGC6752	0.24±0.01	4 stars (Villanova+09)
M4	0.29±0.01	6 stars (Villanova+12)
NGC1851	0.29±0.05	20 stars (Gratton+12)
M5	0.22±0.03	17 stars (Gratton+13)
NGC2808	0.34±0.01	17 stars (Marino+14)
M22	0.34±0.01	29 stars (Gratton+14)
NGC6723	0.37±0.01	2 stars (Gratton+15)
M30	0.252±0.003	24 stars (Mucciarelli+14)
NGC6397	0.241±0.004	35 stars (Mucciarelli+14)

5875 A

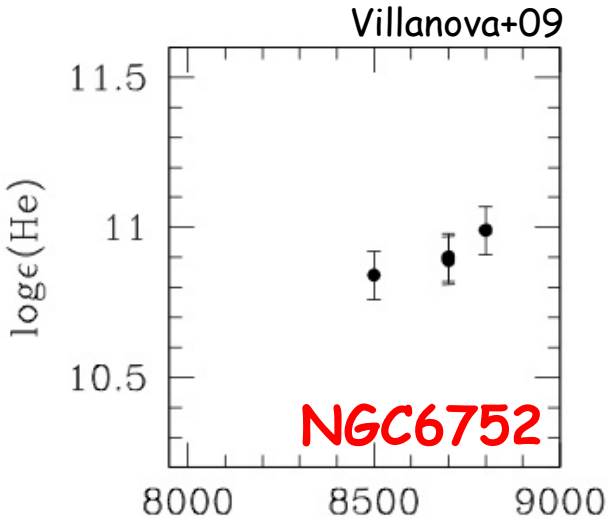
4471A

Internal error
($\sigma/\sqrt{N_{stars}}$)

High-res spectra
(FLAMES)

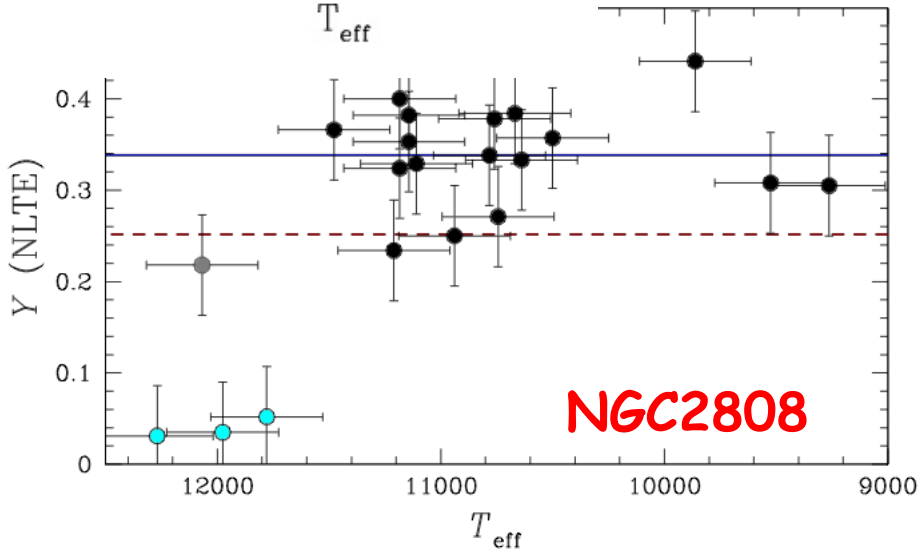
He in GC HB stars

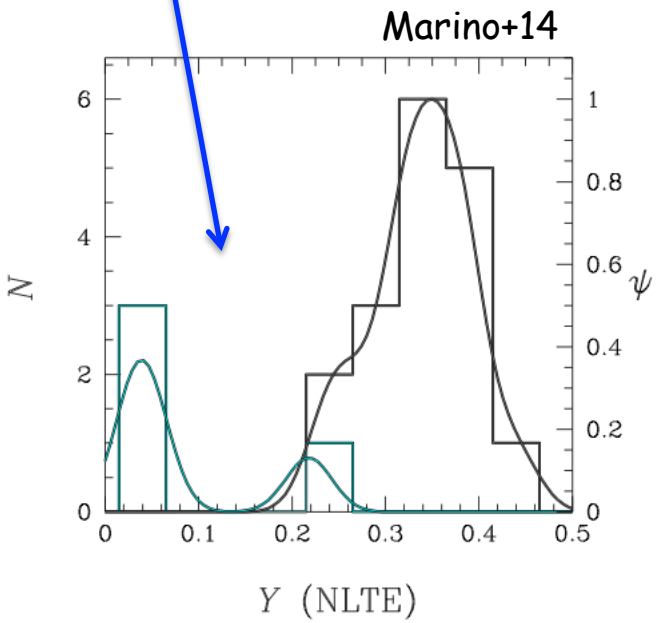
High-SNR spectra



Normal Y (~0.24)

Enriched in Y (~0.34)





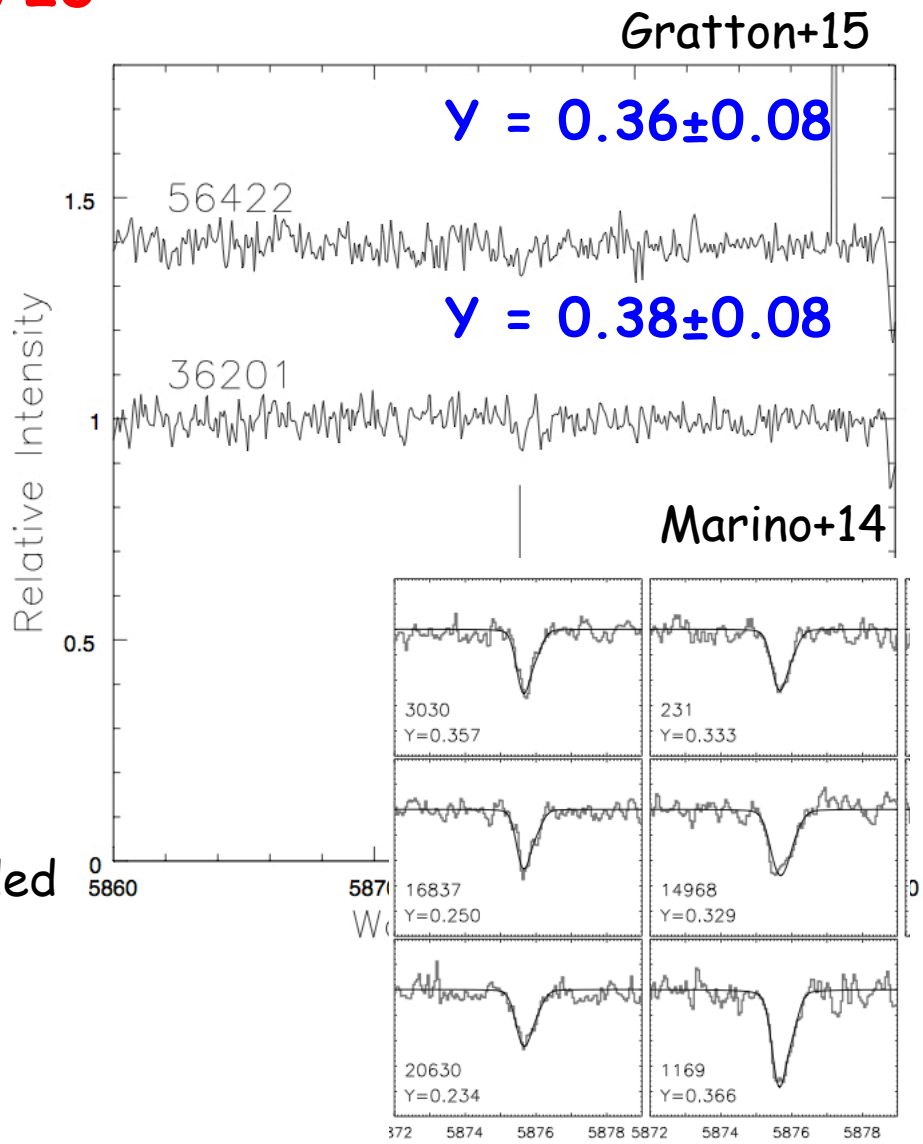
He in GC HB stars – NGC6723

Only 2 stars, both He-enriched
< Y > = 0.37 !!!!

Large uncertainties, real enrichment or false detection?

Caution with these Y values.

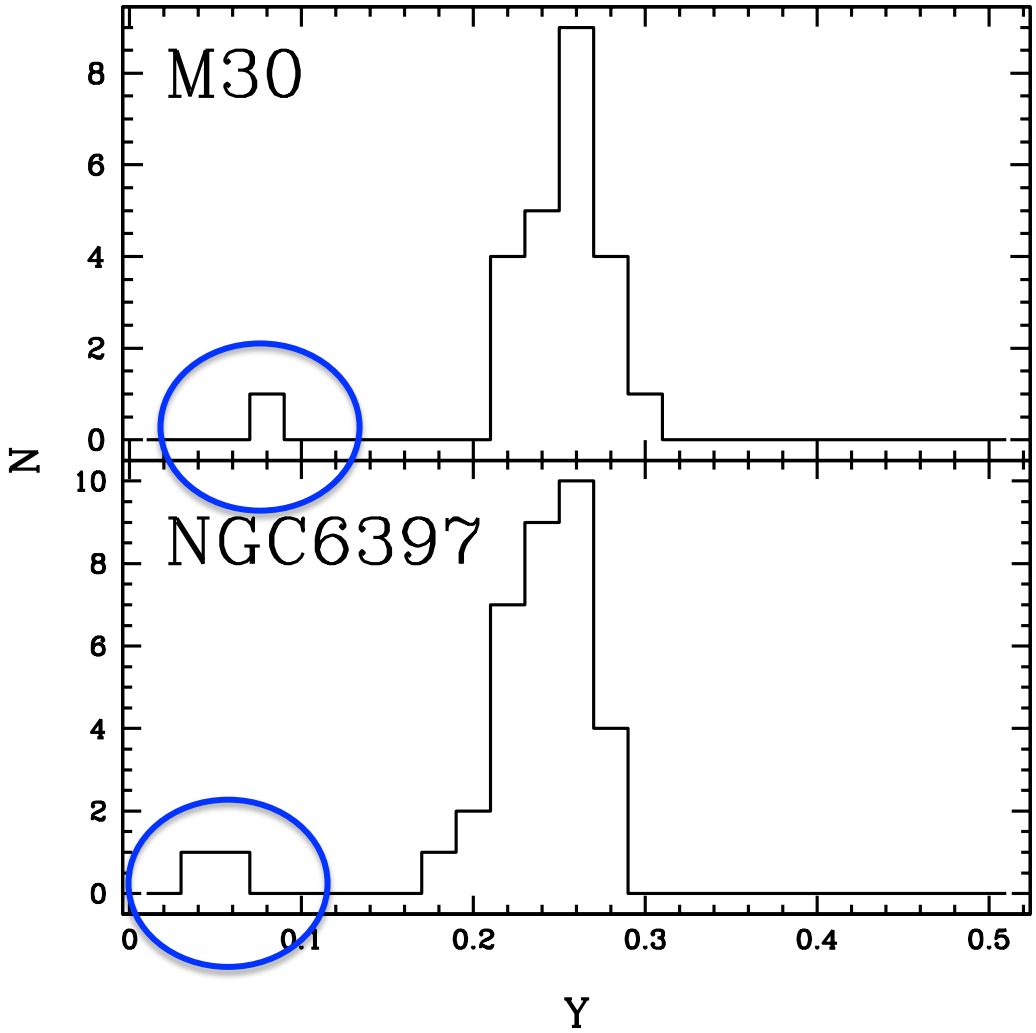
New analysis (higher S/N) are needed for this cluster



He in metal-poor GC HB stars – M30 & NGC6397

FLAMES-GIRAFFE spectra SNR > 100
He line @ 4471A

Mucciarelli+14



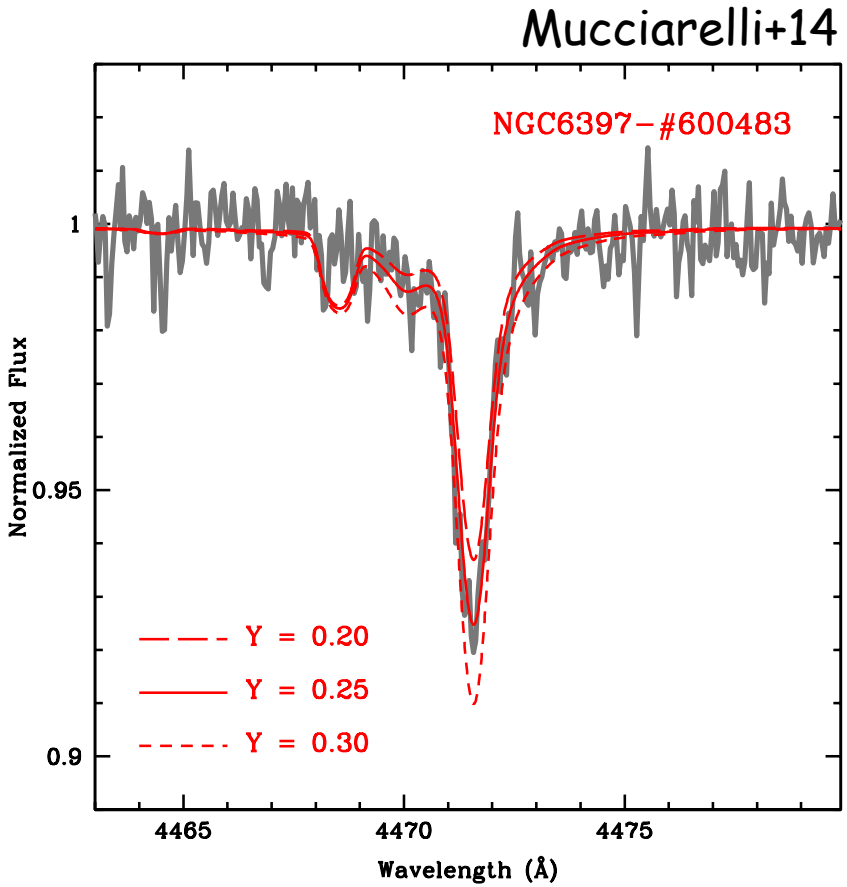
<Y>= 0.252±0.003 (24 stars)

<Y>= 0.241±0.004 (35 stars)

Within the internal uncertainties
(from 0.01 to 0.05)
Y is homogeneous

He in metal-poor GC HB stars – M30 & NGC6397

FLAMES-GIRAFFE spectra SNR > 100
He line @ 4471A



Advantages of He4471 with respect to He5875:
(1) Stronger
(2) Less sensitive to the parameters
(3) Less sensitive to NLTE effects

Future observative perspectives to measure He in GCs

Next de-comissioning of **FLAMES** (2016-2017)

Only **UVES** available but:
- Single object
- Not so efficient. 10 hours of VLT time for V=16 (M5), 2 hours for V=14 (M4)

Next advent of **ESPRESSO** (first light 2016?)
blue-optical range, high-res (up to 120000), simultaneous use of all the 4 UTs , single-object

Next advent of **HIRES**@E-ELT

Use of other facilities (**Keck, Subaru** …)

Summary

- First He abundances measured in GC HB stars
- A few of them based on high SNR spectra
- We need to re-analyse some GCs with better spectra
- Best strategy: high SNR spectra and simultaneous measure of different He lines (in particular 4471 A)
- A *single-object* future ?

The End