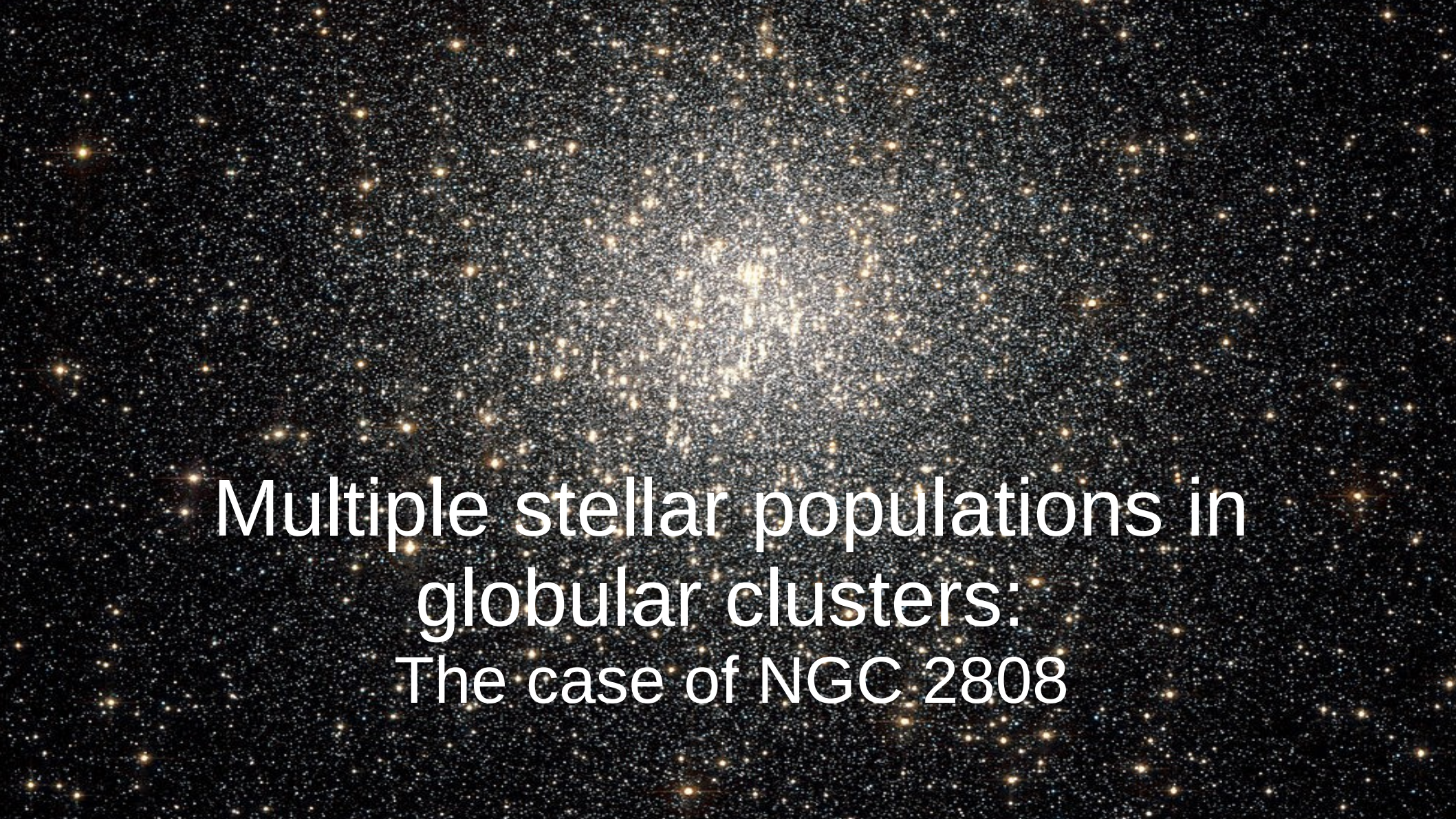
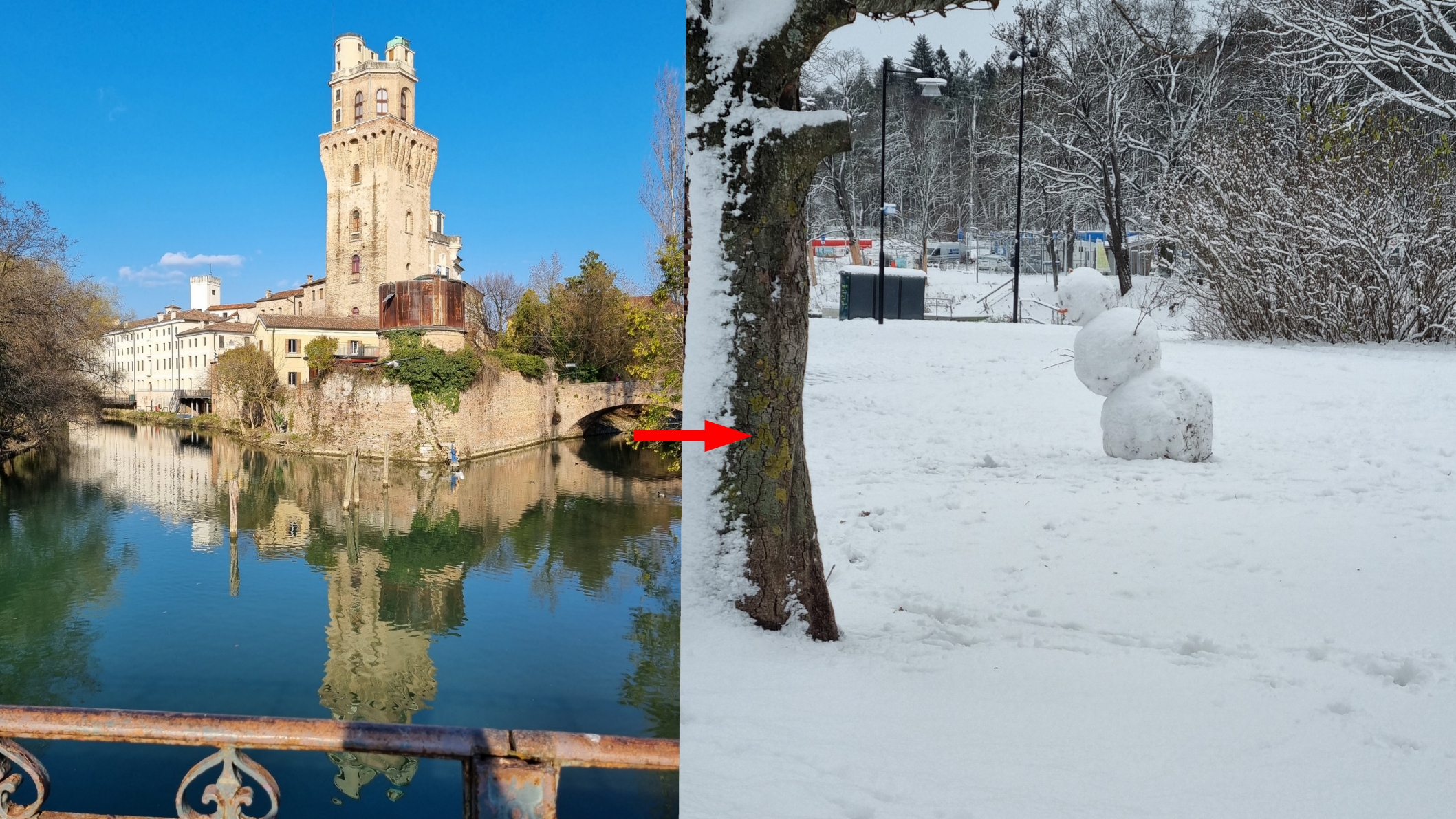


Multiple stellar populations in globular clusters:
The case of NGC 2808

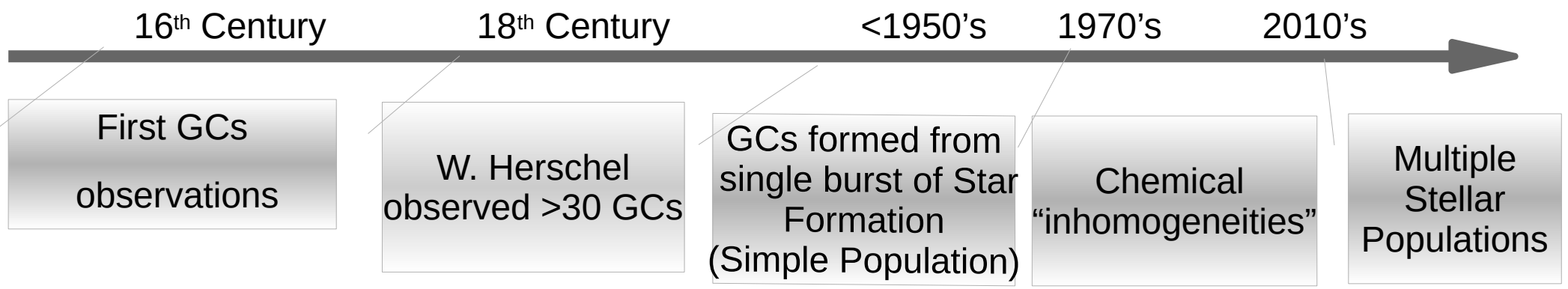
- Post-doc at Universita di Padova from 2020 to 2022

- A. F. Marino, A. Milone, E. Dondoglio, S. Jang, M. Legnardi, A. Mohandasan, G. Cordoni, E. Lagioia, T. Ziliotto.



What is a globular cluster (GC)?

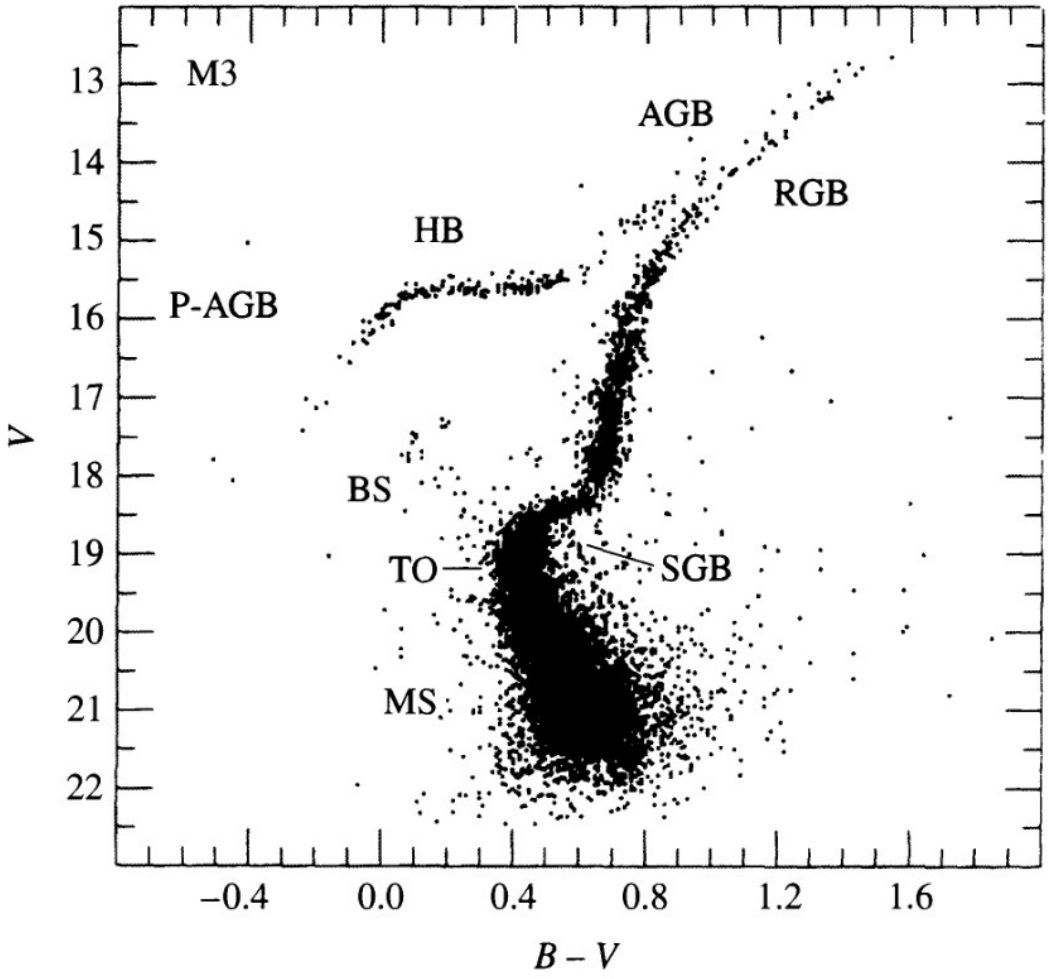
- Old, bright and compact stellar agglomerates.



CMD from Renzini & Pecci 1988.

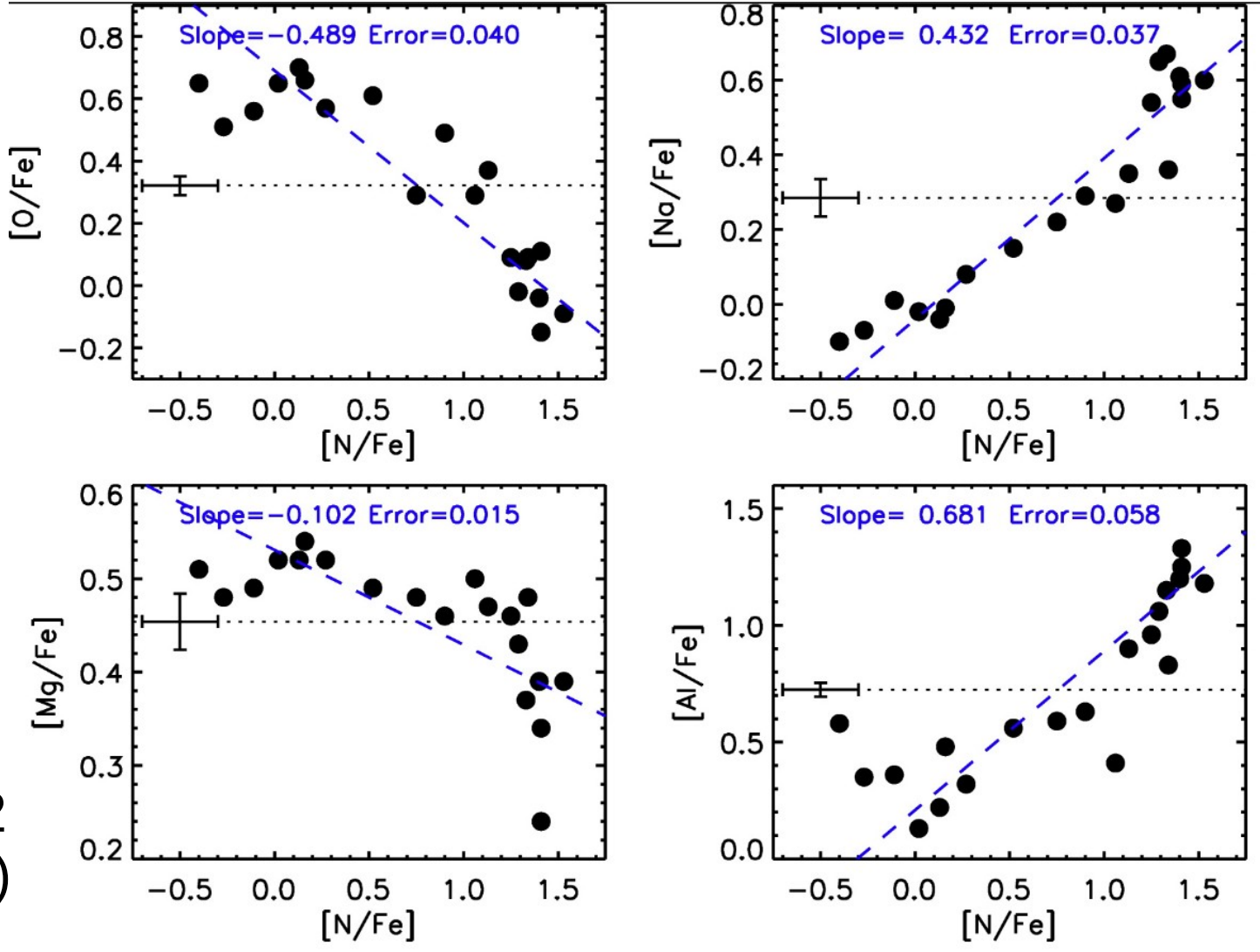
ALL stars (should) have:

- Same age
- Same chemical composition



Chemical

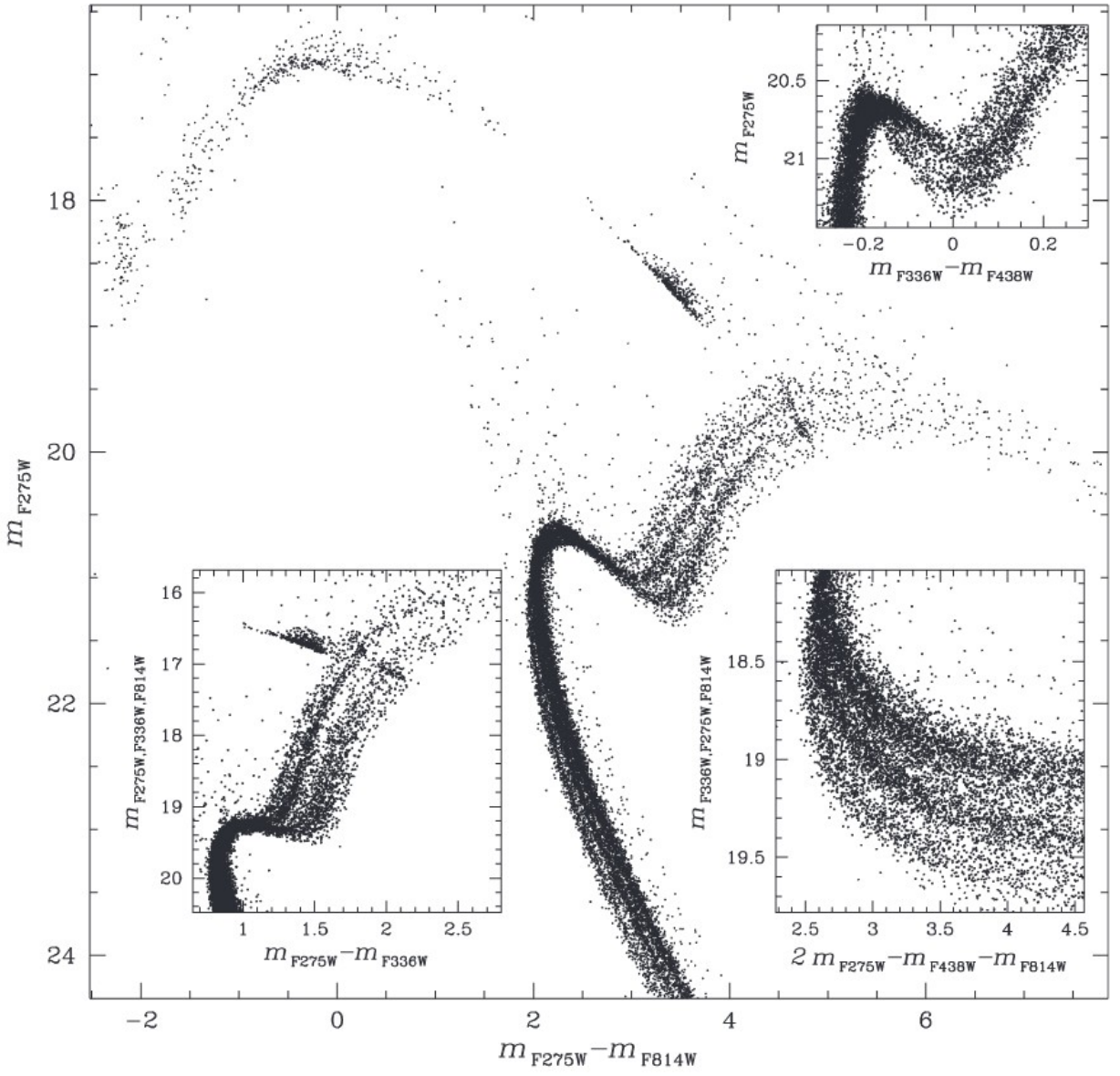
"inhomogeneities"



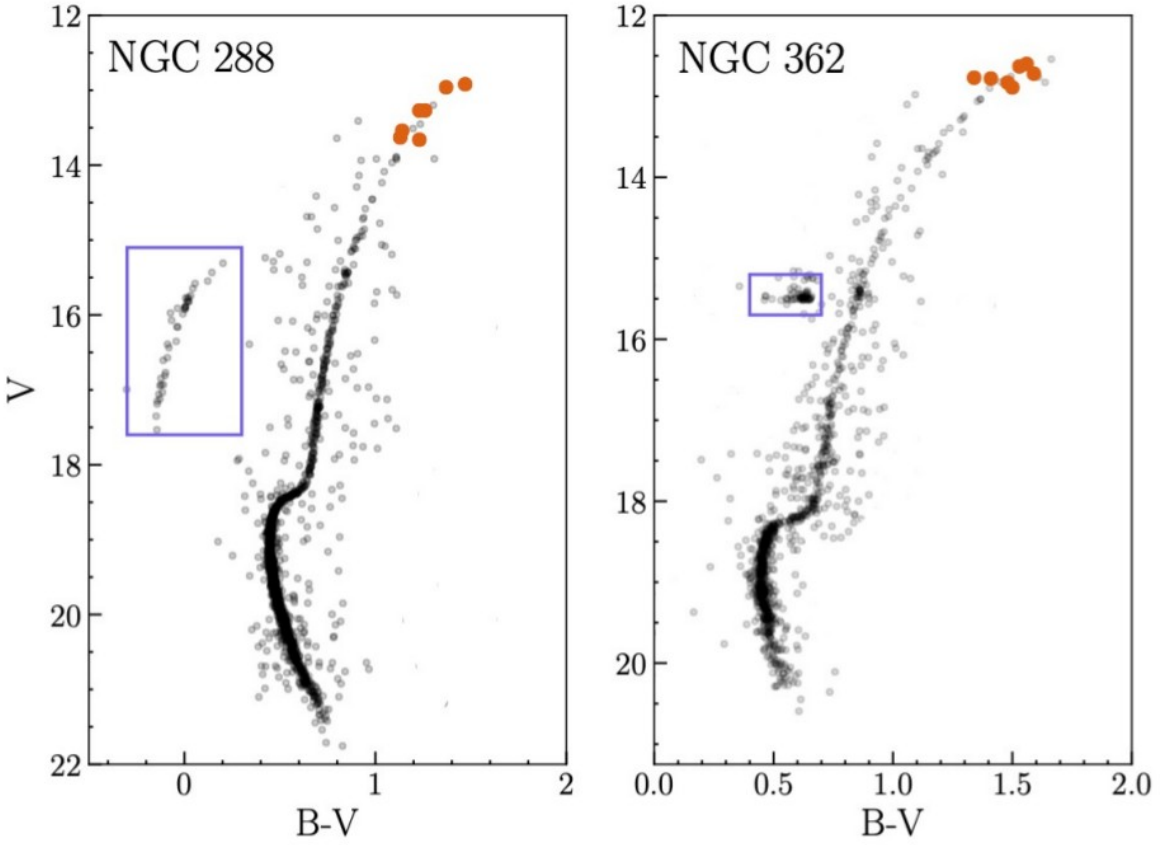
NGC 6752
(Yong+2008)

Multiple Populations (MP)

NGC 2808
(Milone+2015)



The second parameter problem

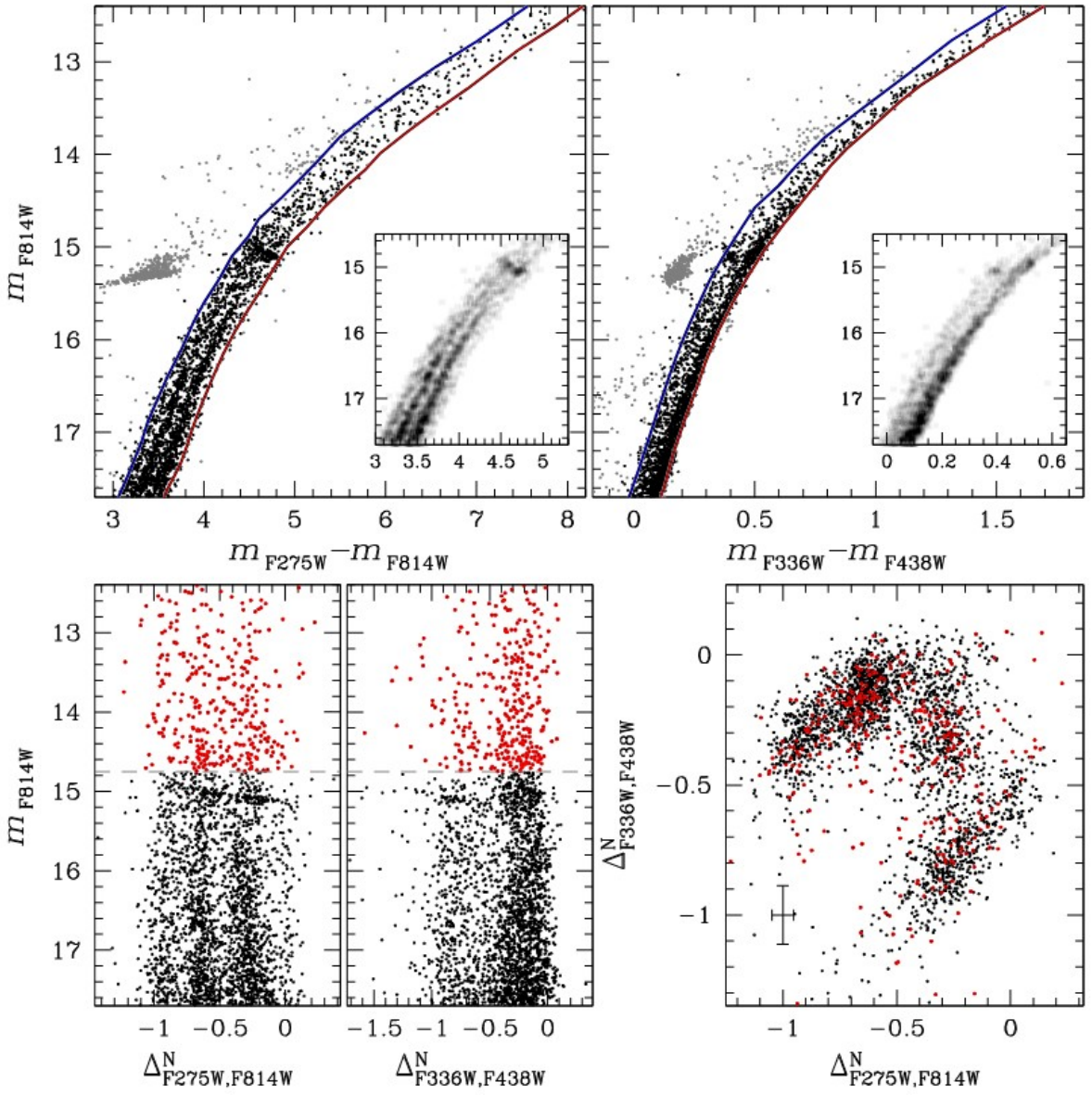


NGC 288 – [Fe/H]~-1.39
NGC 362 – [Fe/H]~-1.33

Monty+2022

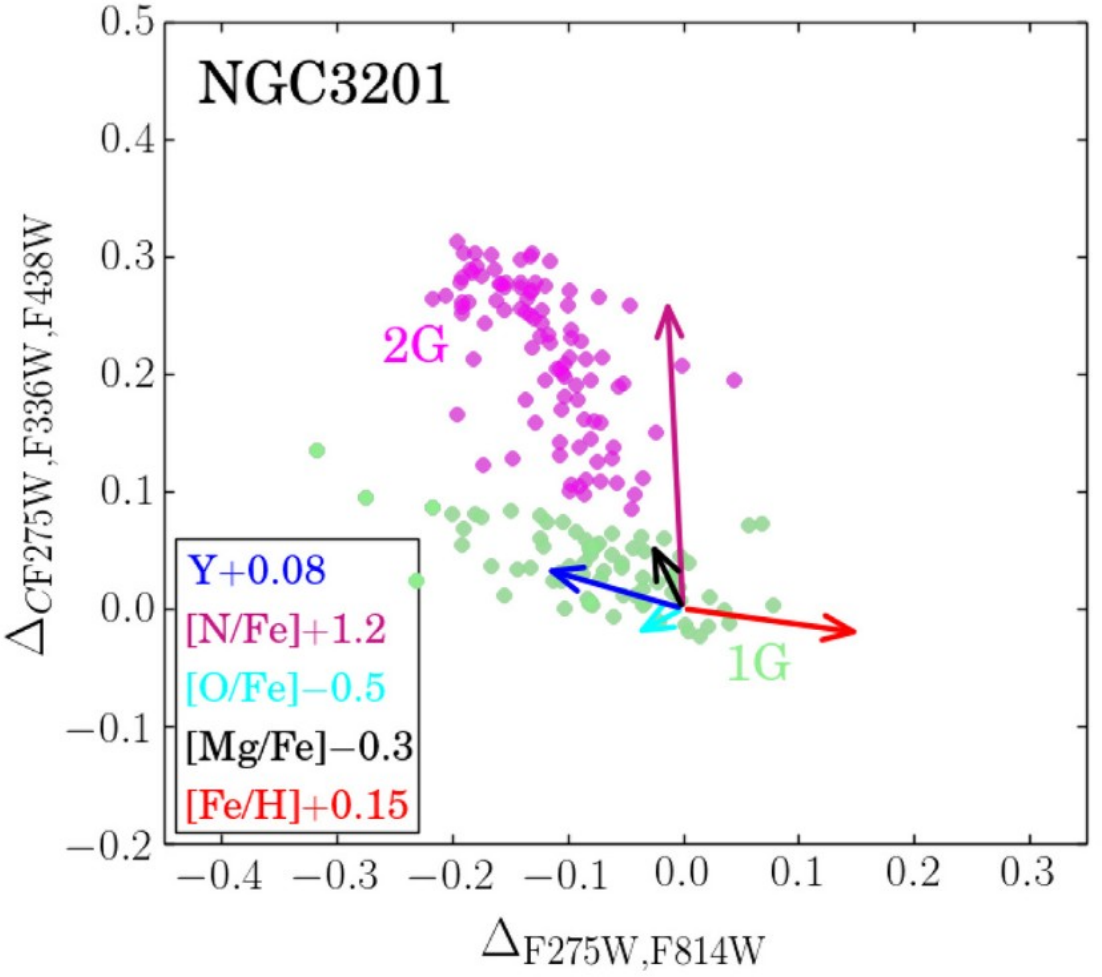
Chromosome Maps (ChM)

NGC 2808
(Milone+2015)



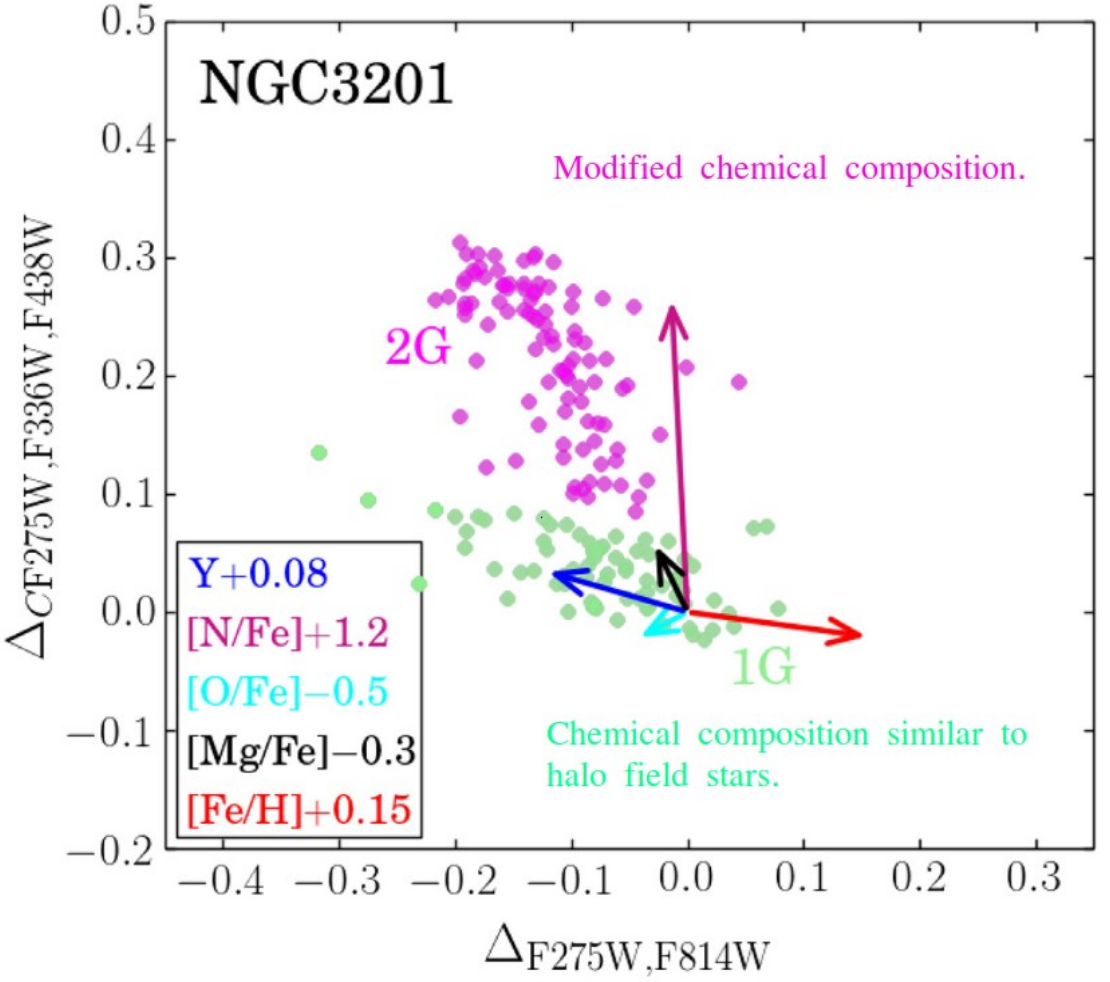
ChMs are excelent photometric tools to infer chemical composition of specific elements.

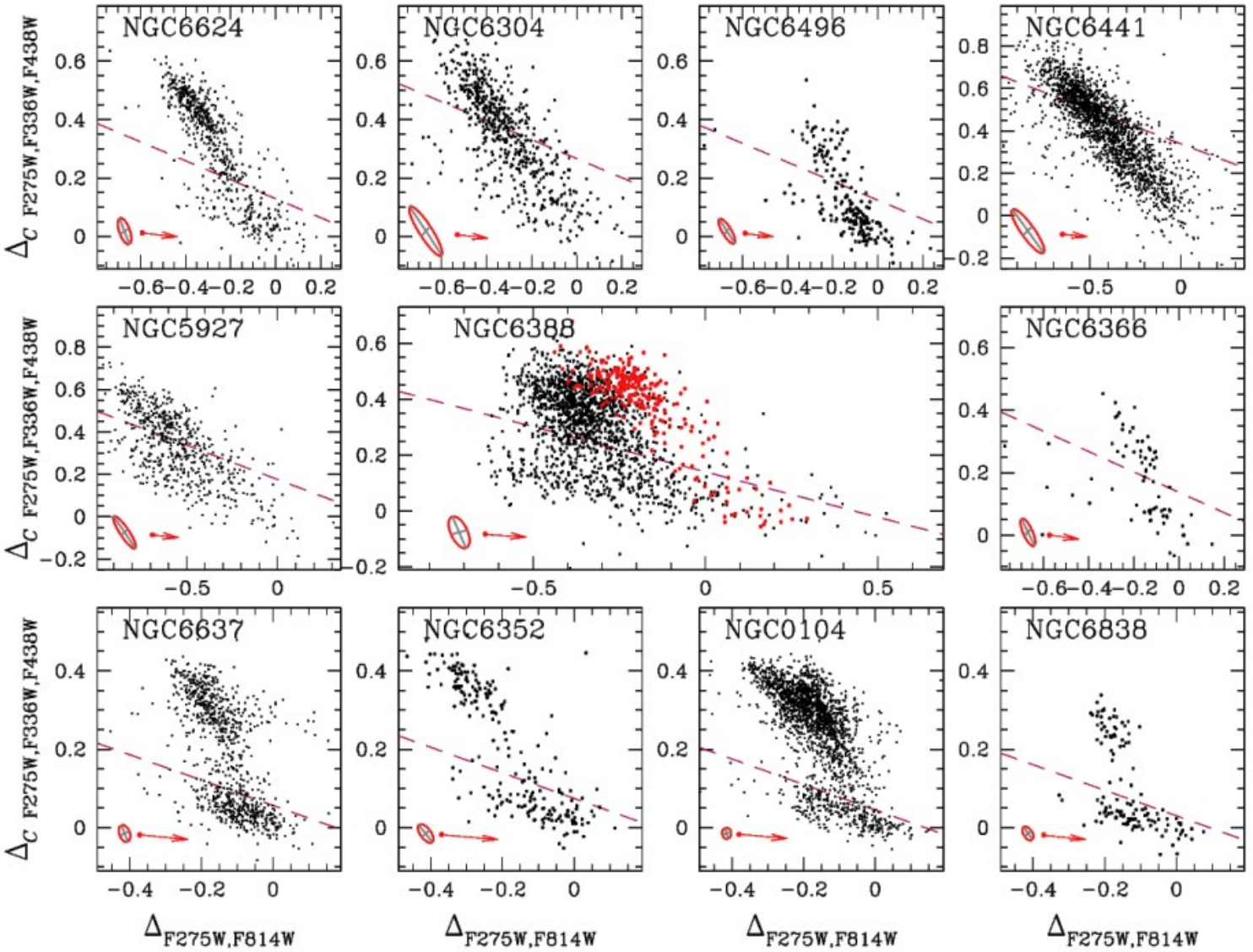
Marino+2019



ChMs are excelent photometric tools to infer chemical composition of specific elements.

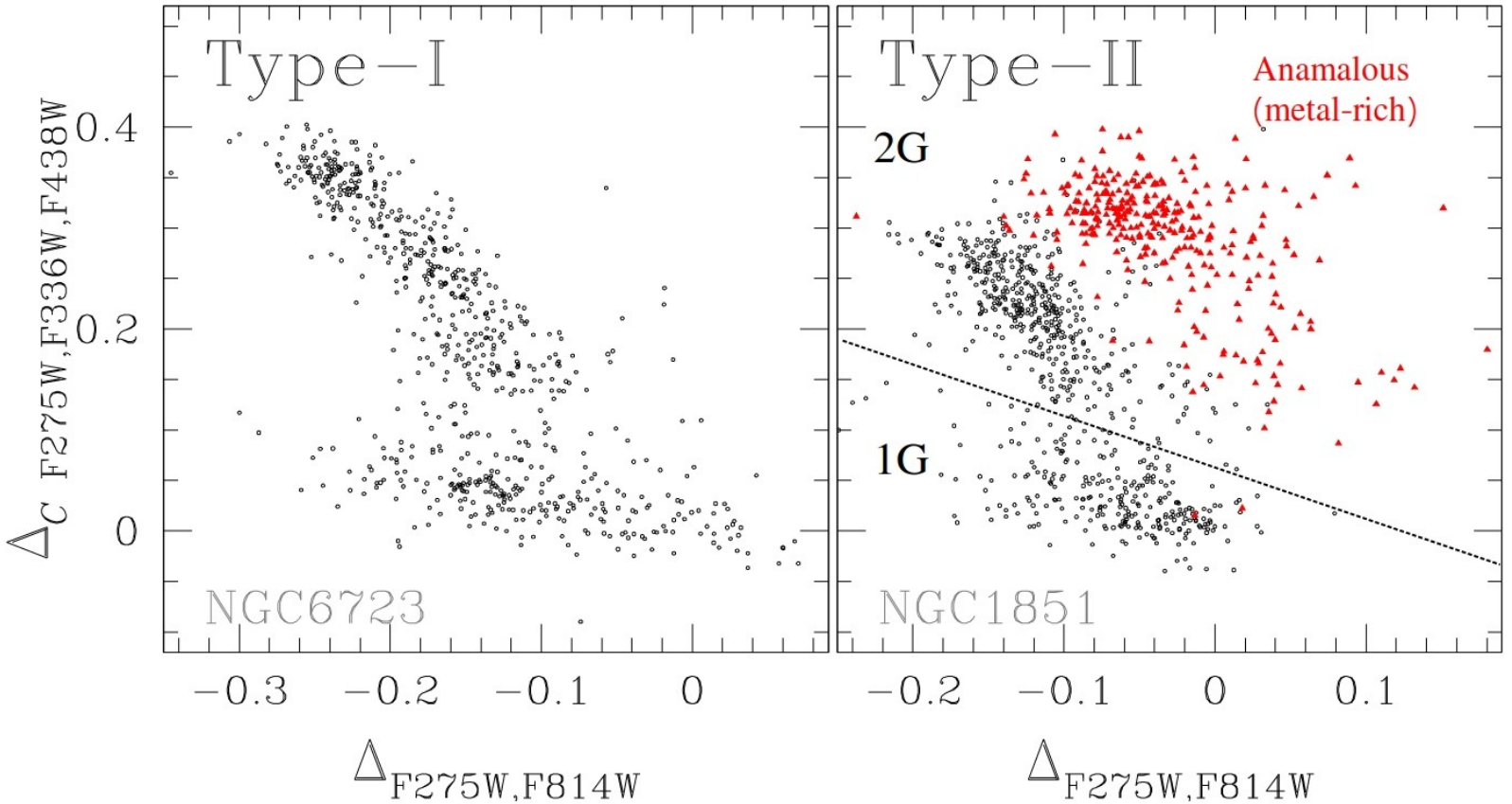
Marino+2019




NGC6624
NGC6304
NGC6496
NGC6441
NGC5927
NGC6388
NGC6366
NGC6637
NGC6352
NGC0104
NGC6838
$\Delta_{C\ F275W,F336W,F438W}$
$\Delta_{F275W,F814W}$

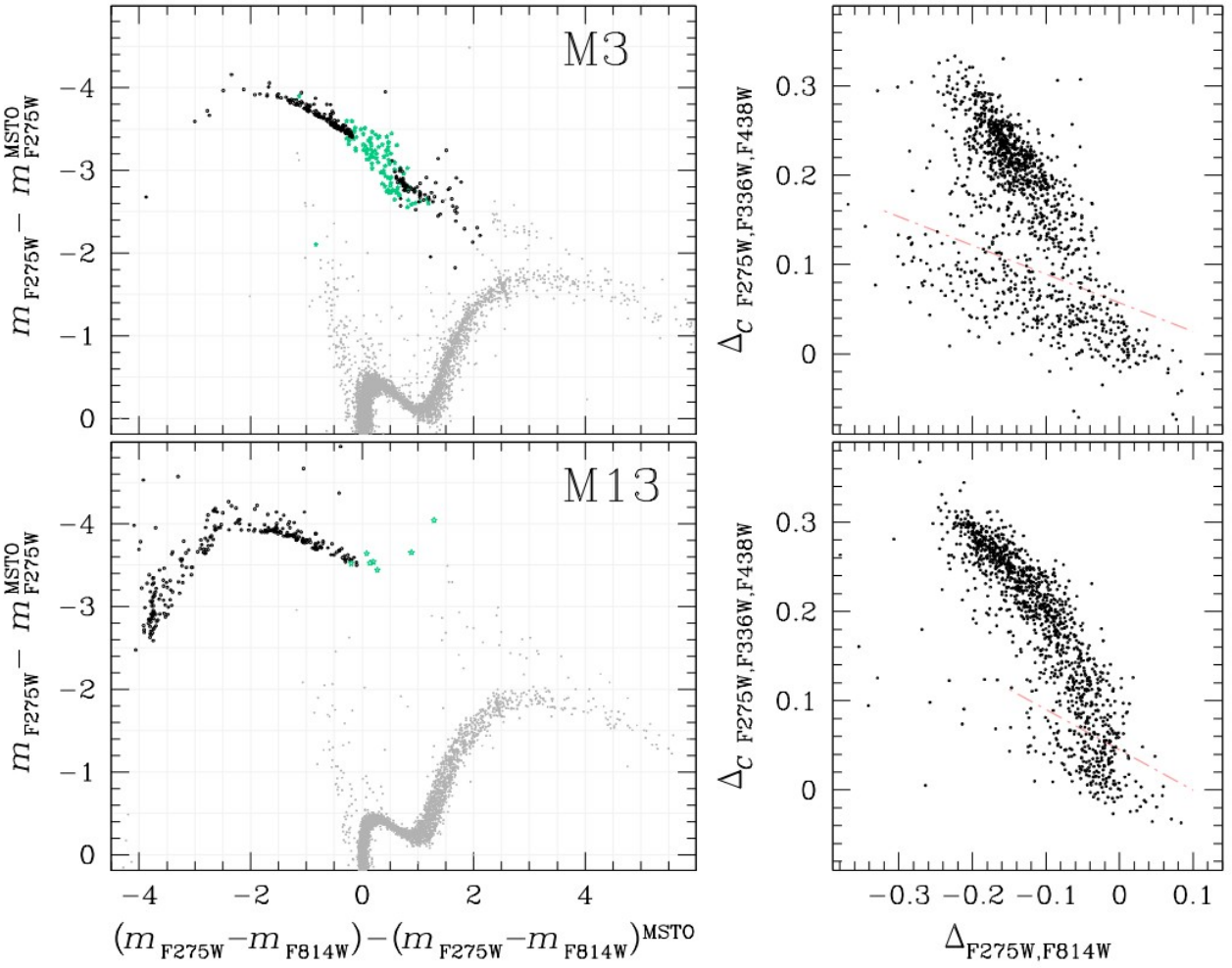
Milone+2017

Type of GCs

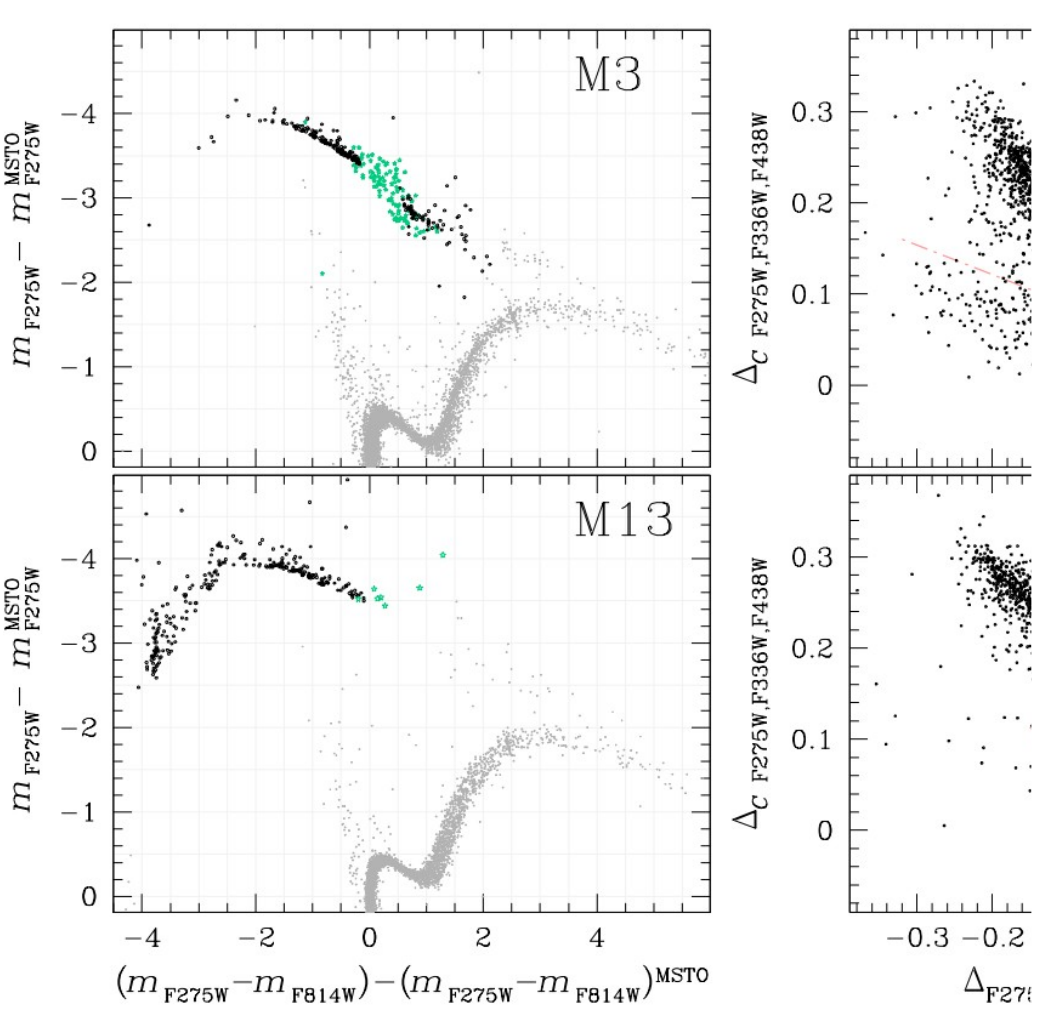


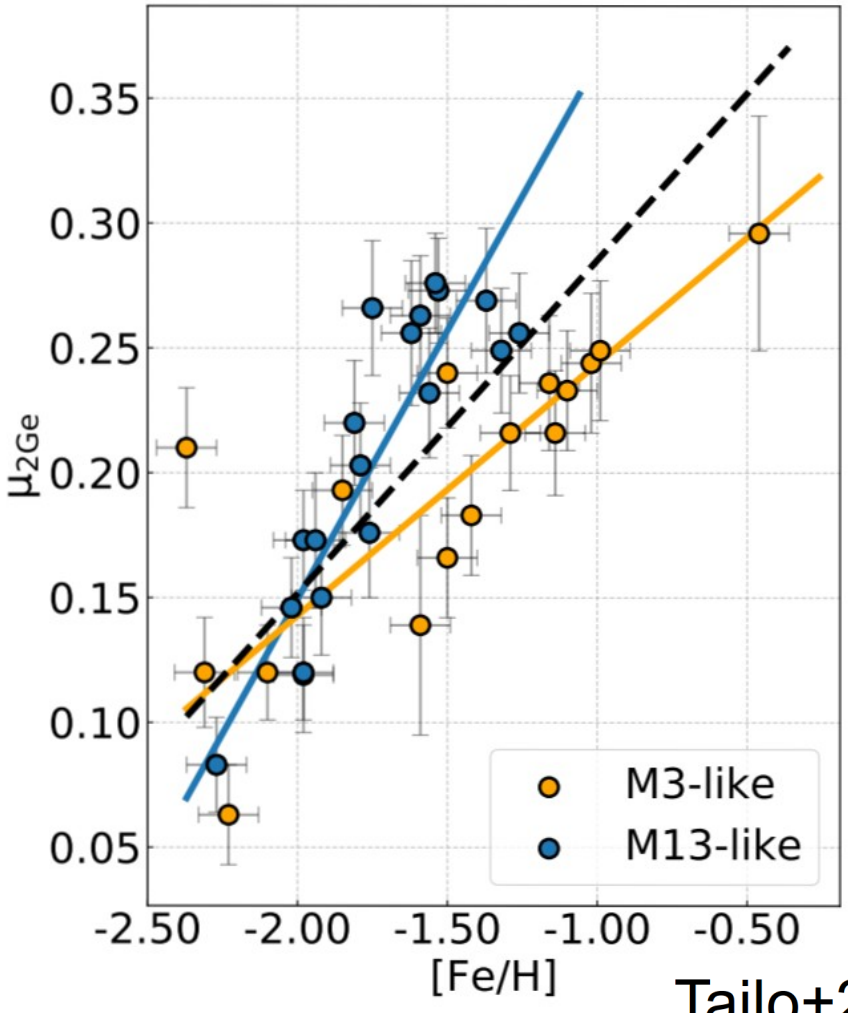
Milone & Marino 2022, modified.

M3- vs. M13-like GCs



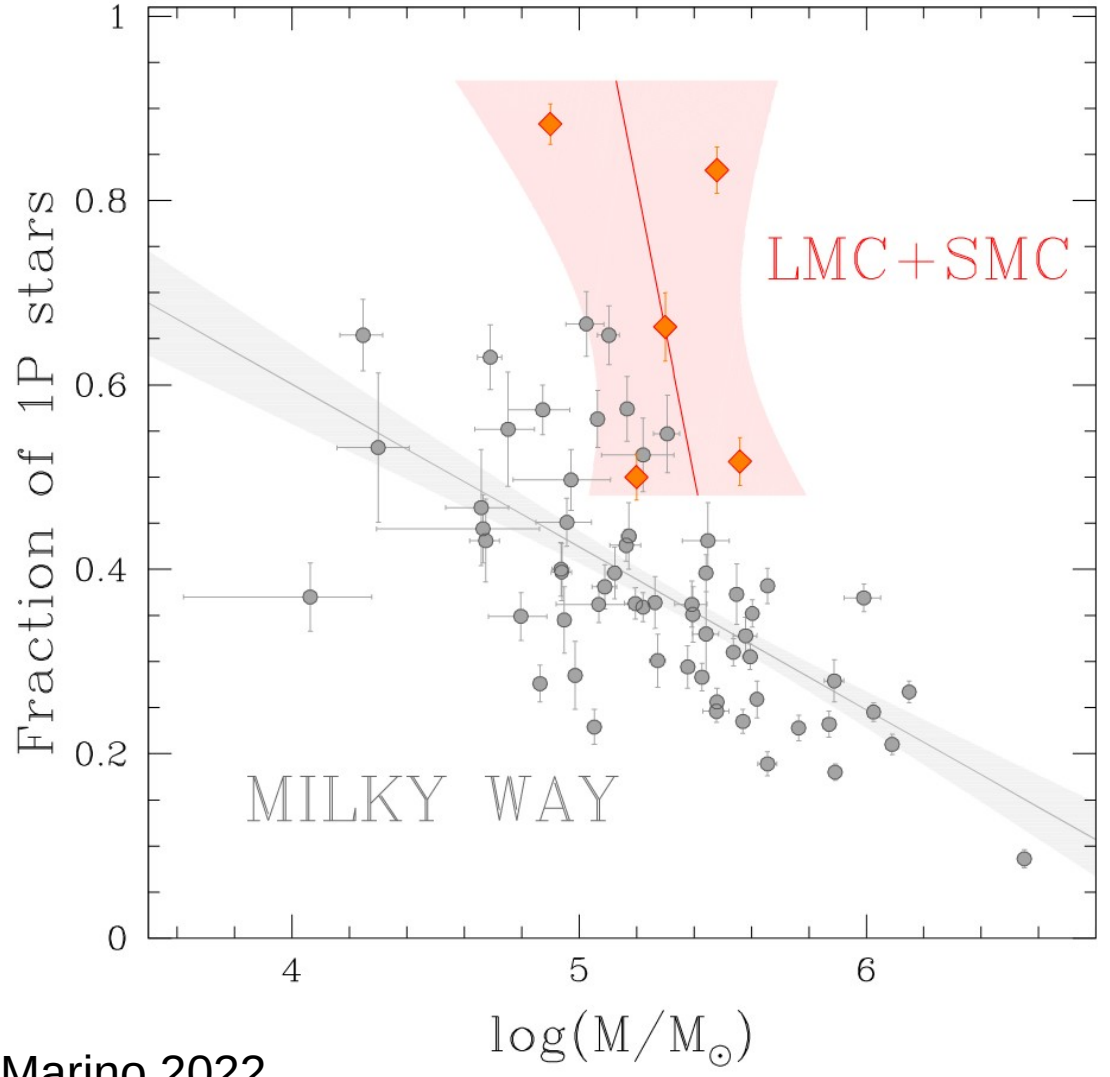
M3- vs. M13-like GCs





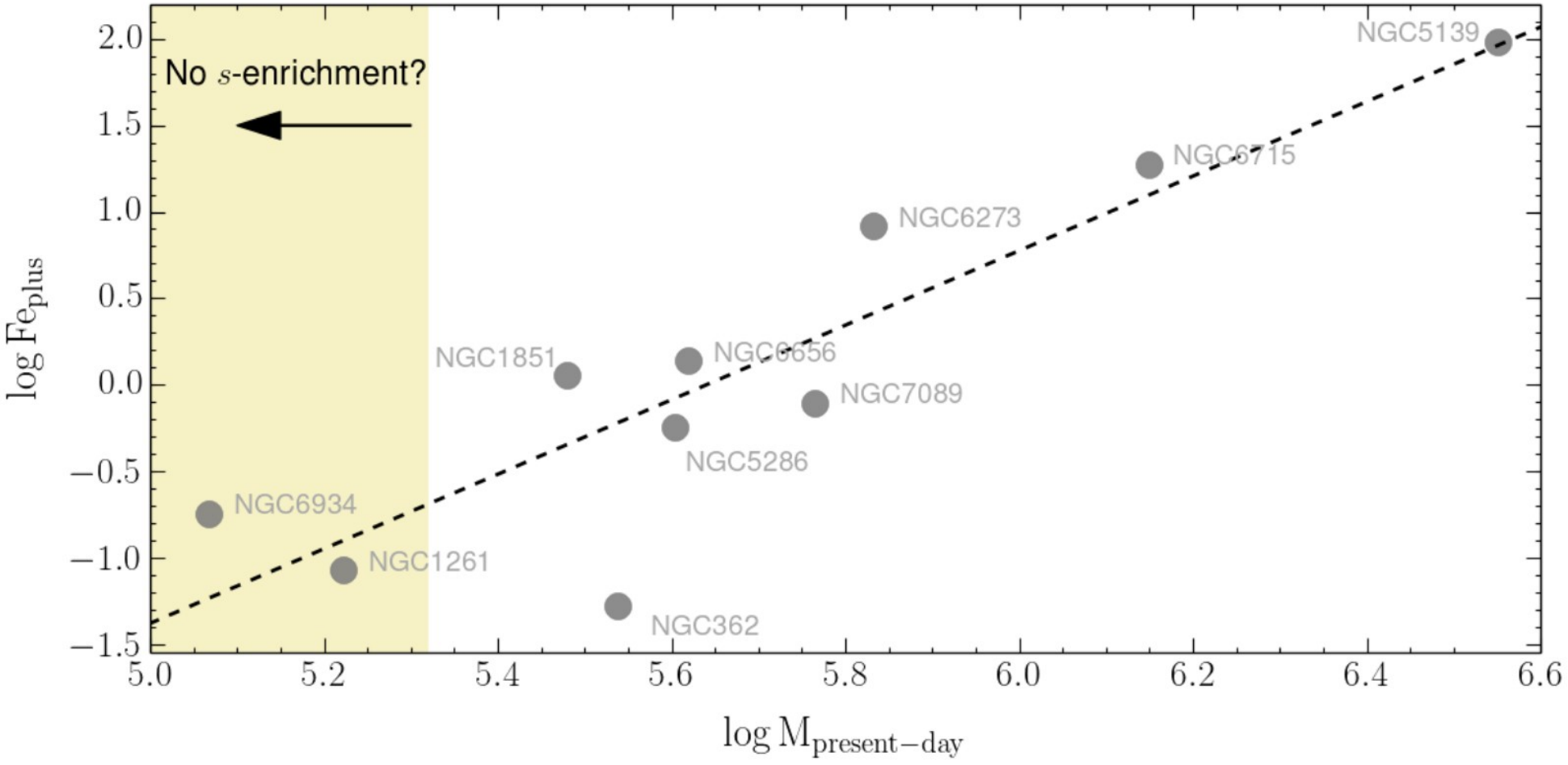
Tailo+2020

Most massive GCs present a lower fraction of 1P stars in comparison with less massive ones.



Milone & Marino 2022

Type II GCs:


No s-enrichment?
NGC5139
NGC6715
NGC6273
NGC1851
NGC6656
NGC7089
NGC5286
NGC6934
NGC1261
NGC362
$\log \mathrm{Fe_{plus}}$
$\log \mathrm{M_{present-day}}$
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
5.0
5.2
5.4
5.6
5.8
6.0
6.2
6.4
6.6

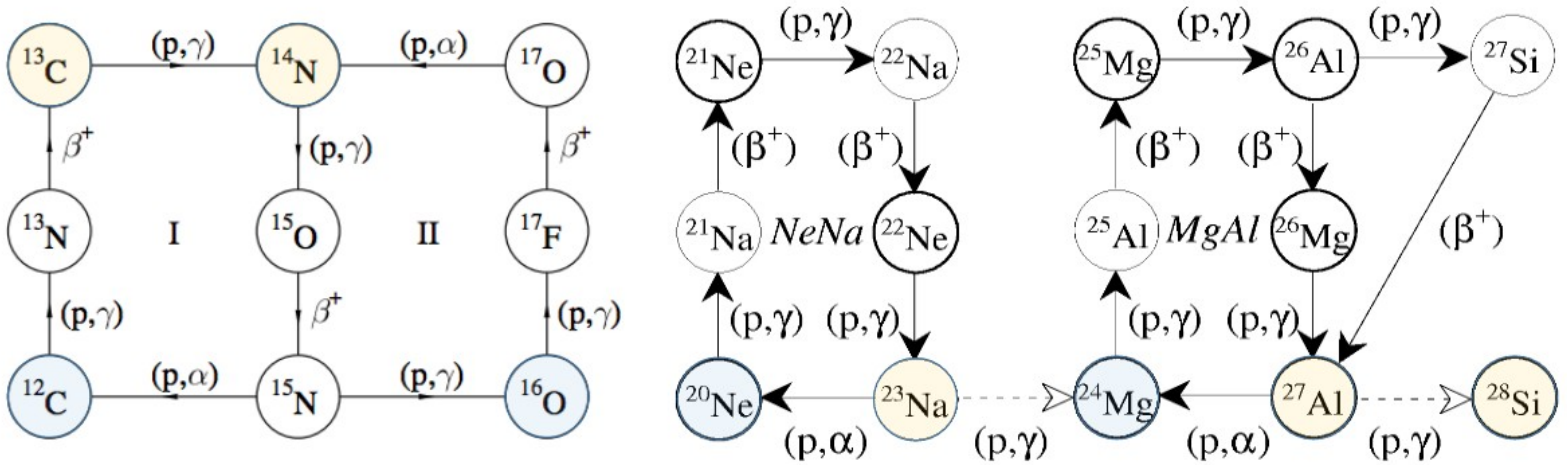
Formation scenarios

- The multiple-population pattern in globular clusters may either suggest that different **stellar populations formed at different times**, with gas from 1G stars (**AGB or massive stars**) diluted with the pristine gas forming the subsequent generations of stars (e.g., D'Ercole et al. 2008),

- or that the different populations were **formed at the same time** but at different conditions, with second populations stars having accreted material from early disc accretion from **massive binaries or from a supermassive star** (Bastian et al. 2013, Gieles et al. 2018).

Possible formation scenarios:

- AGBs
- Fast-rotating massive stars (FRMSs)
- Interacting massive binaries (IMB)
- Early disc accretion = FRMSs + IMB
- Super-massive stars (SMS)
- Stellar mergers

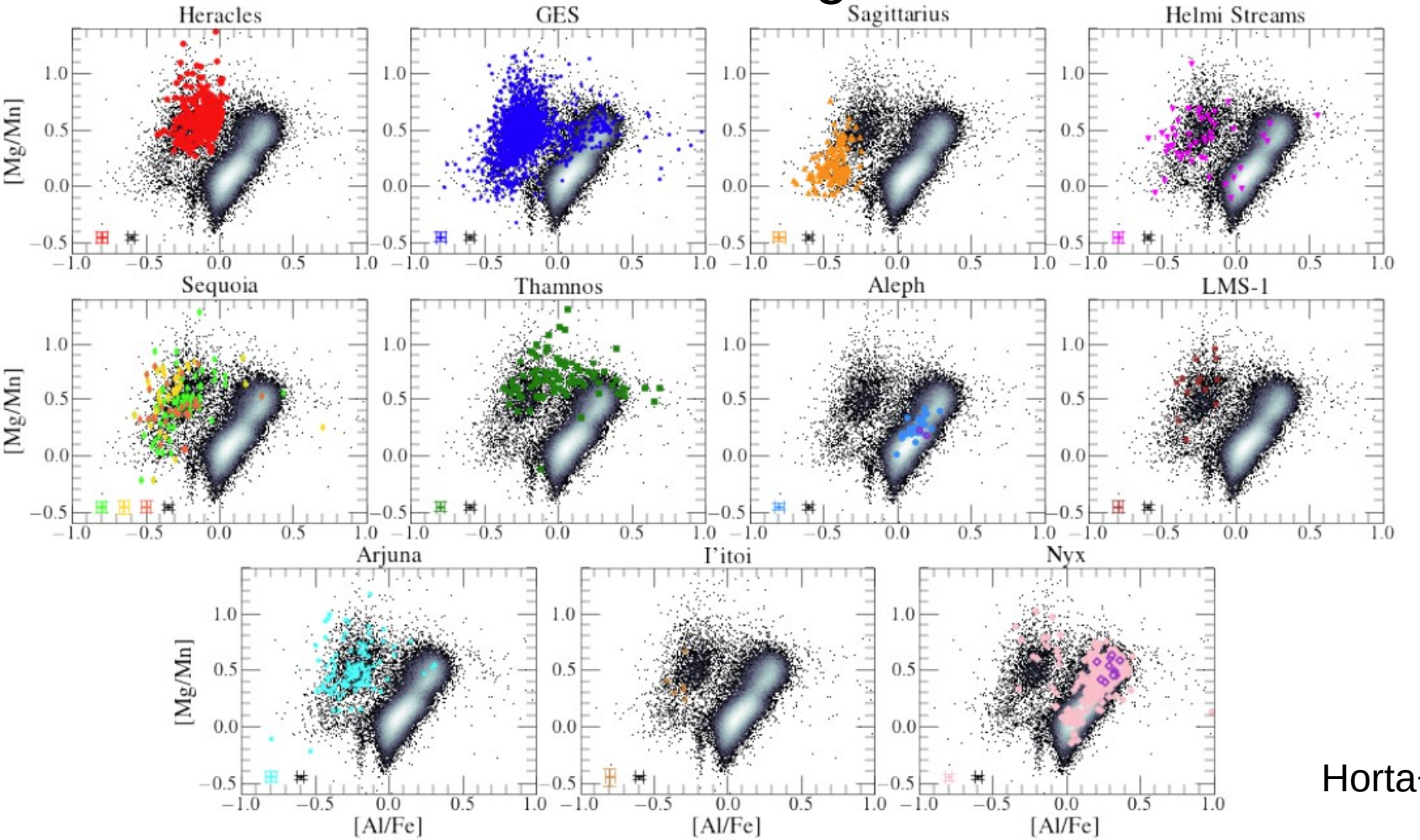


10 MK **40 MK** **70 MK** **80-180 MK**

Burning Temperature

Chemical abundances are important to disentangle the scenarios!

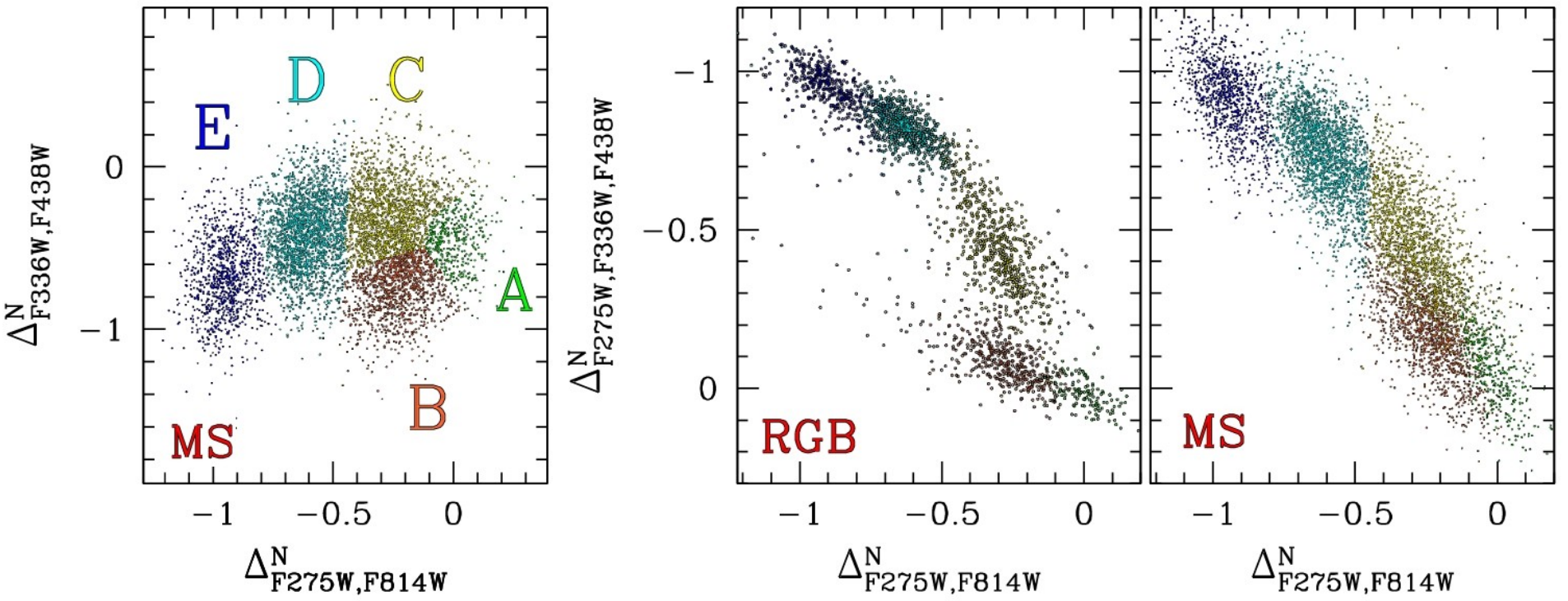
GCs accreted from dGal mergers with MW?



Horta+2022

Why NGC 2808?

- One of the most massive type I GC ($7.42 \pm 0.05 \times 10^5 M_{sun}$).
- Spectacular ChM with a large number of stellar populations (at least five in the RGB).
- Large internal He variation ($\Delta(Y)=0.089 \pm 0.010$).


E
D
C
A
B
MS
RGB
MS
0
−1
−0.5
$\Delta^{N}_{F336W,F438W}$
$\Delta^{N}_{F275W,F336W,F438W}$
$\Delta^{N}_{F275W,F814W}$

Milone+2015

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of the
ROYAL ASTRONOMICAL SOCIETY

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The chemical compositions of multiple stellar populations in the globular cluster NGC 2808

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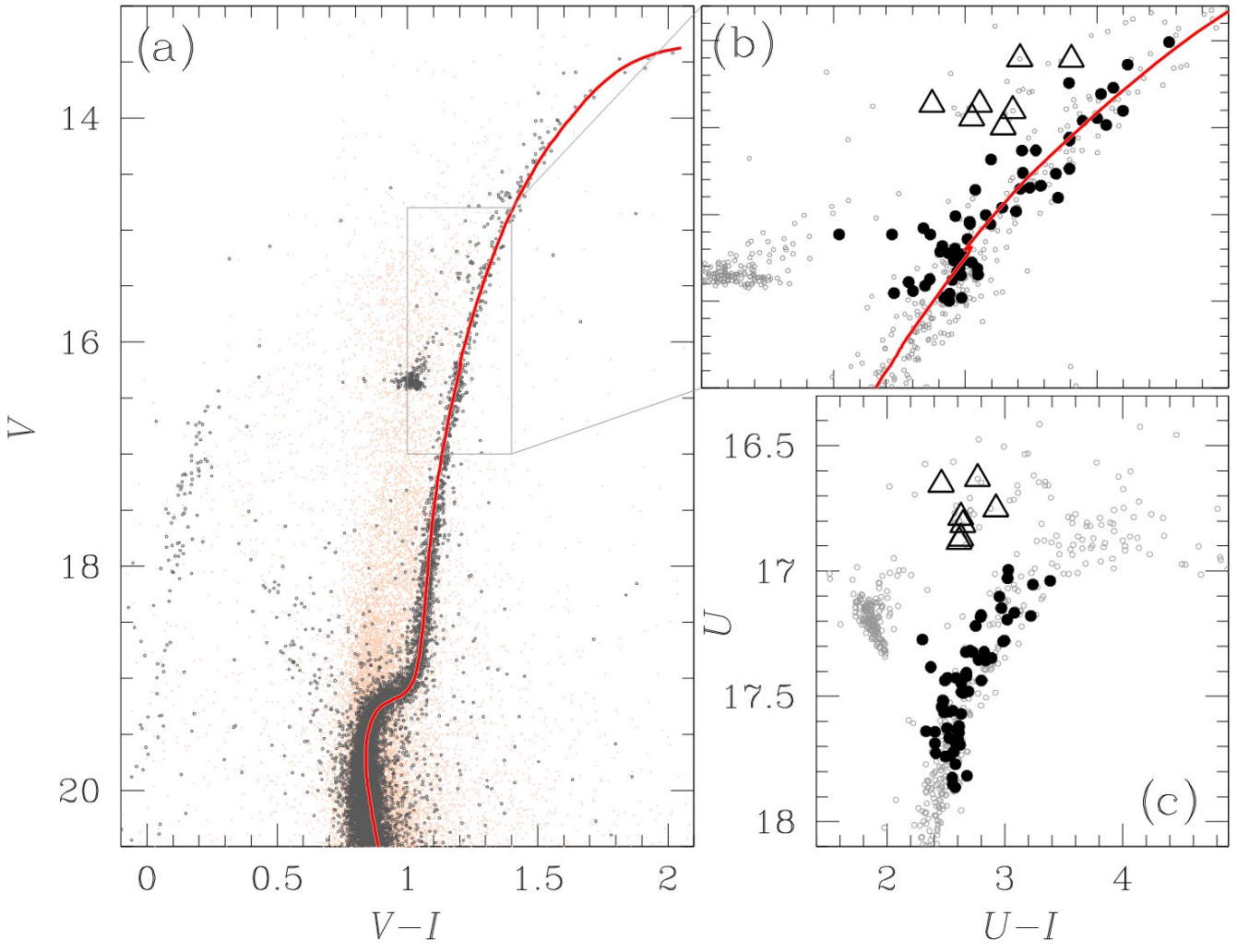
ABSTRACT

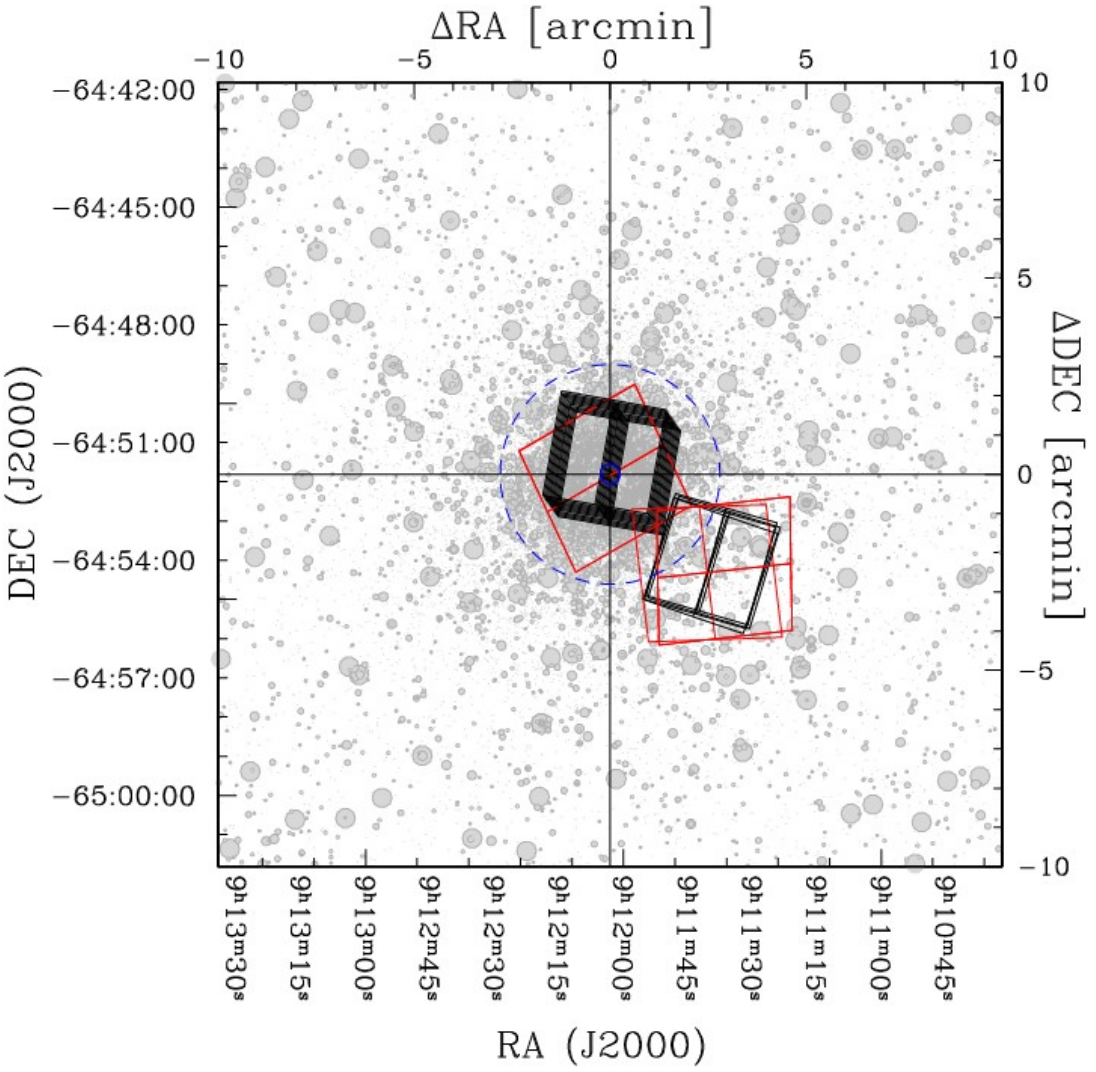
Pseudo two-colour diagrams or Chromosome maps (ChM) indicate that NGC 2808 host five different stellar populations. The existing ChMs have been derived by the *Hubble Space Telescope* photometry, and comprise of stars in a small field of view around the cluster centre. To overcome these limitations, we built a ChM with *U*, *B*, *I* photometry from ground-based

Combine both photometry (ground-based+HST) and spectroscopy (FLAMES/VLT) in a '*population assignment*' attempt.

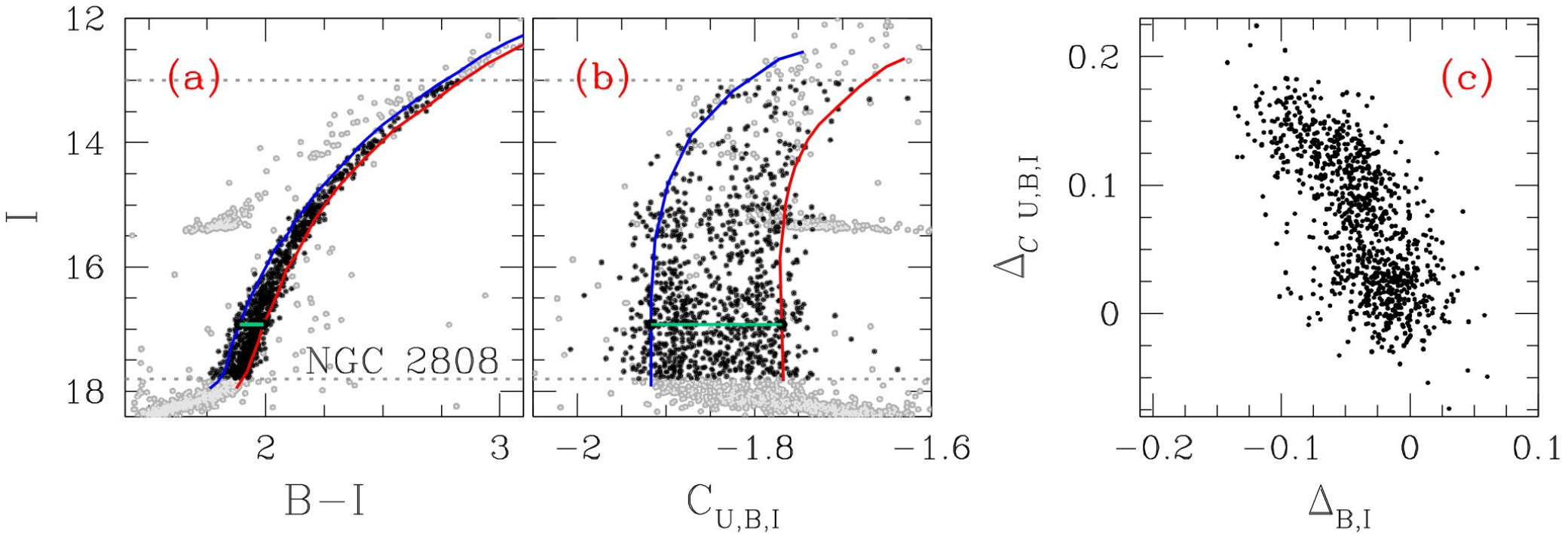


- HST photometry is available for a small field of view > this restrict GC studies to innermost cluster regions.

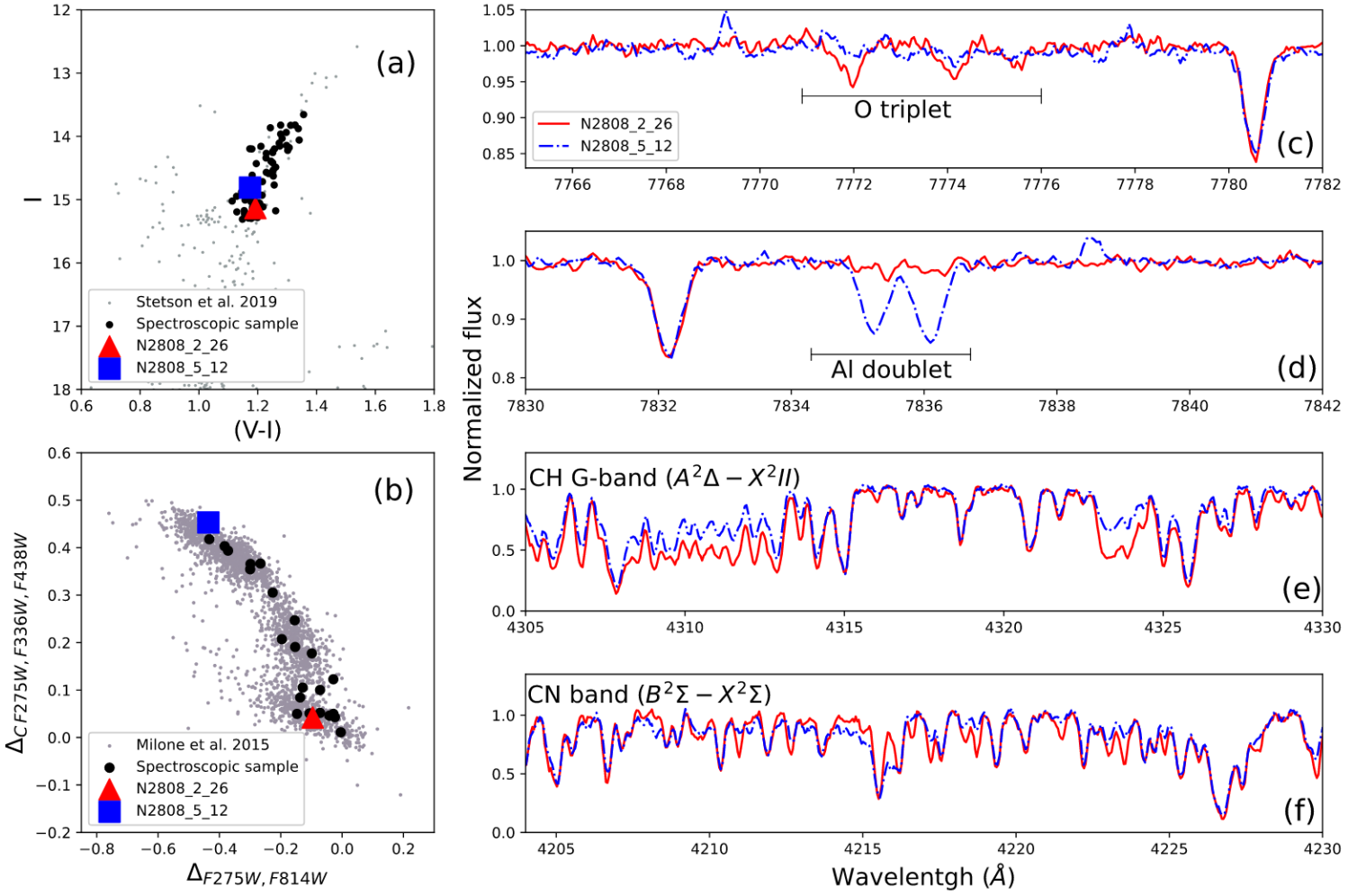
- Wide-field photometry extend the investigation of multiple populations to the entire cluster.

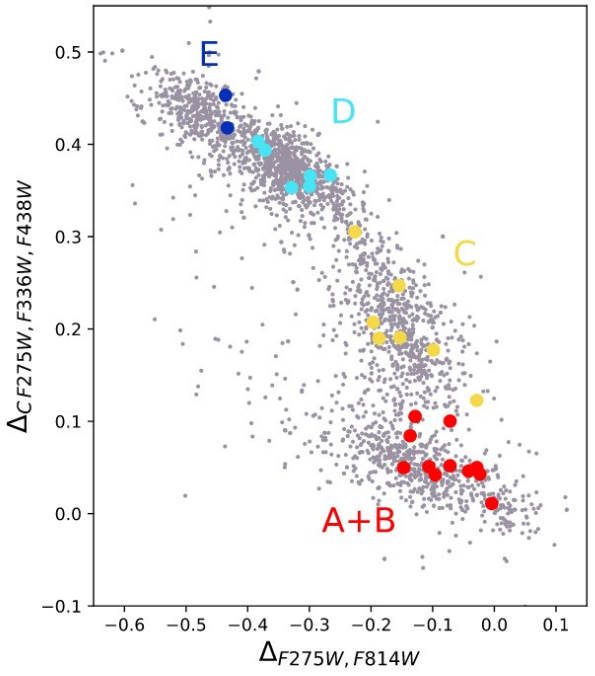


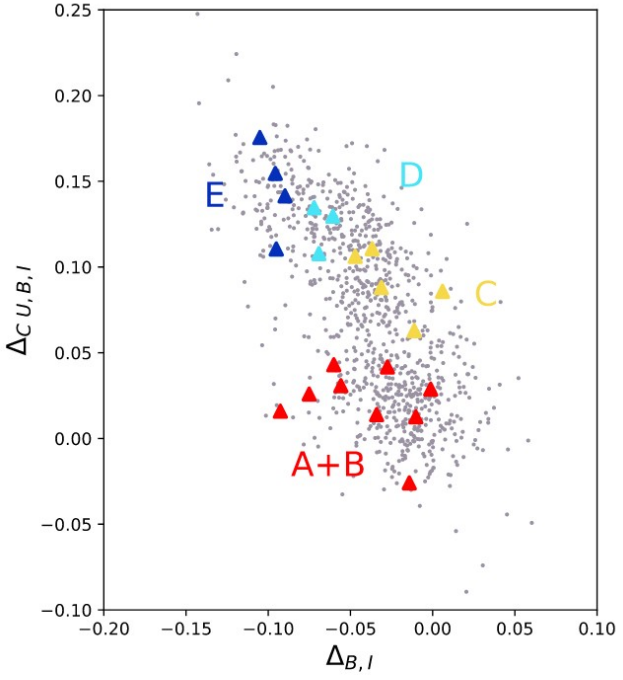
New ChM with ground based photometry:



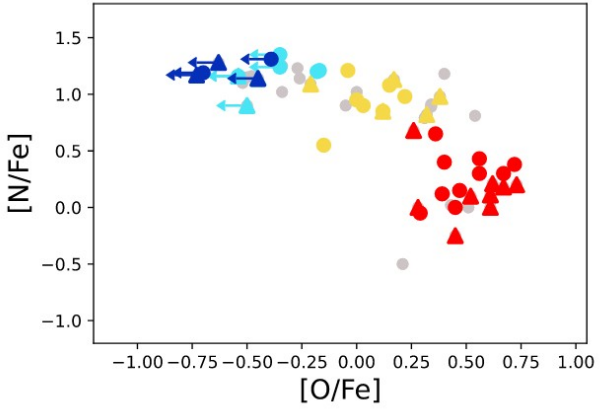
High resolution spectroscopy:

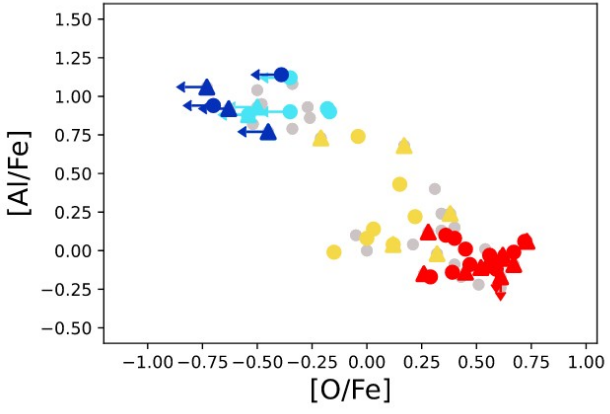



E
D
C
A+B
$\Delta_{CF275W,F336W,F438W}$
$\Delta_{F275W,F814W}$

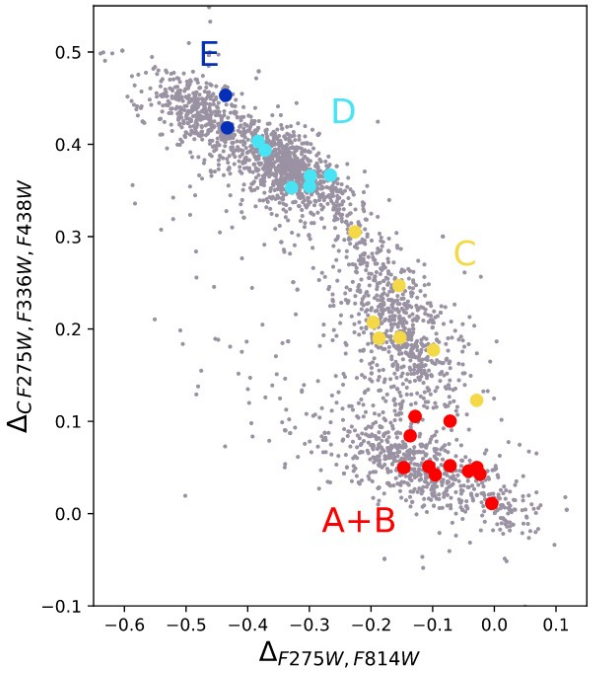

E
D
C
A+B
$\Delta_{C\,U,B,I}$
$\Delta_{B,I}$

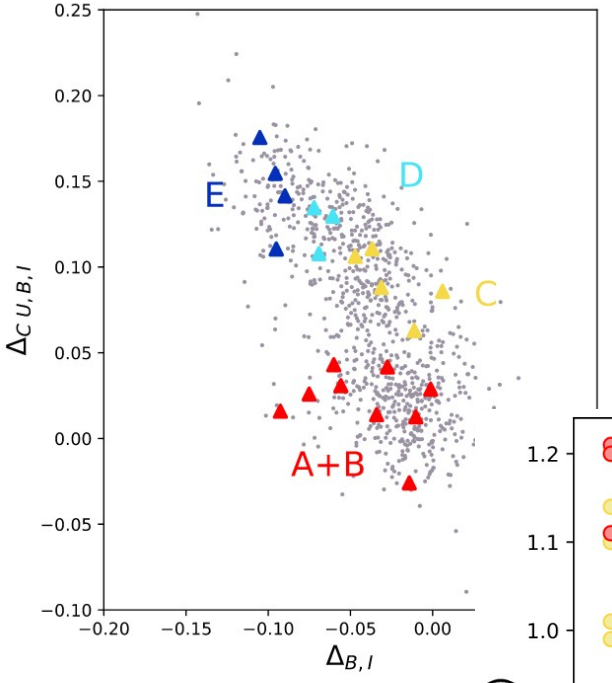
RGB sample

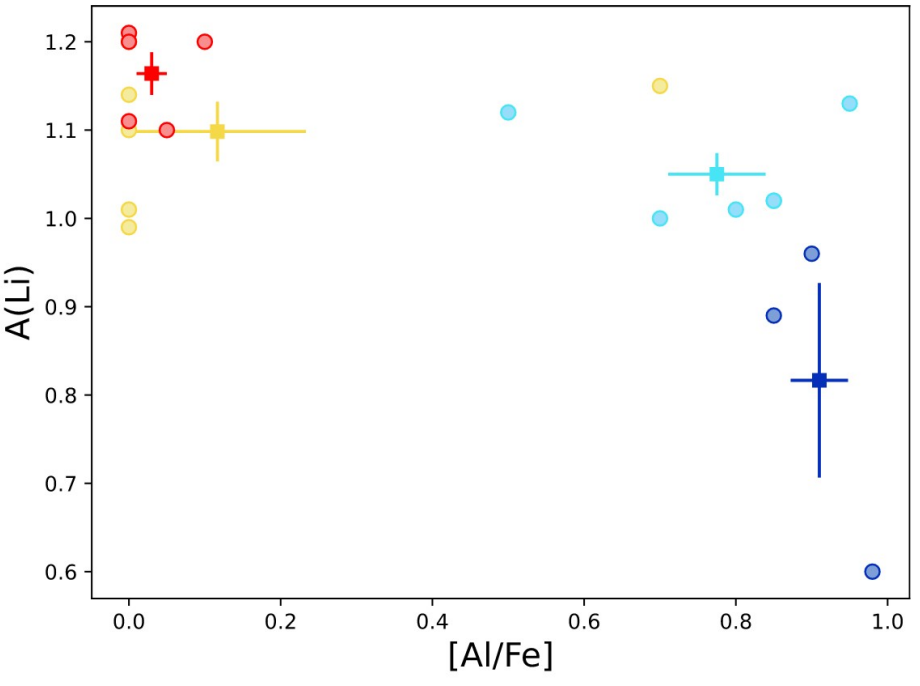

[N/Fe]
[O/Fe]

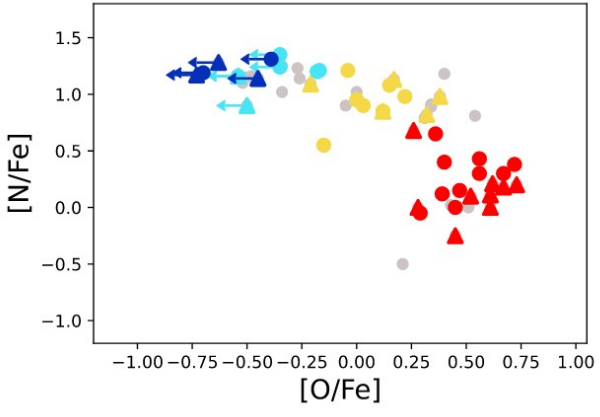

[Al/Fe]
[O/Fe]

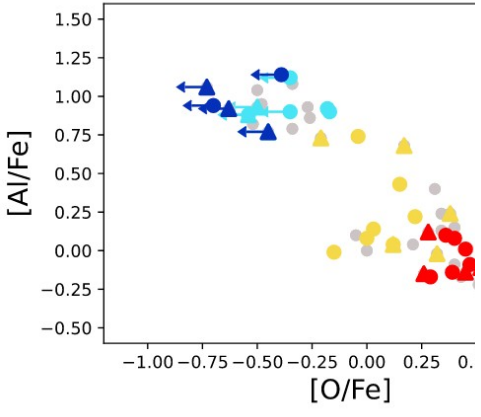
RGB sample

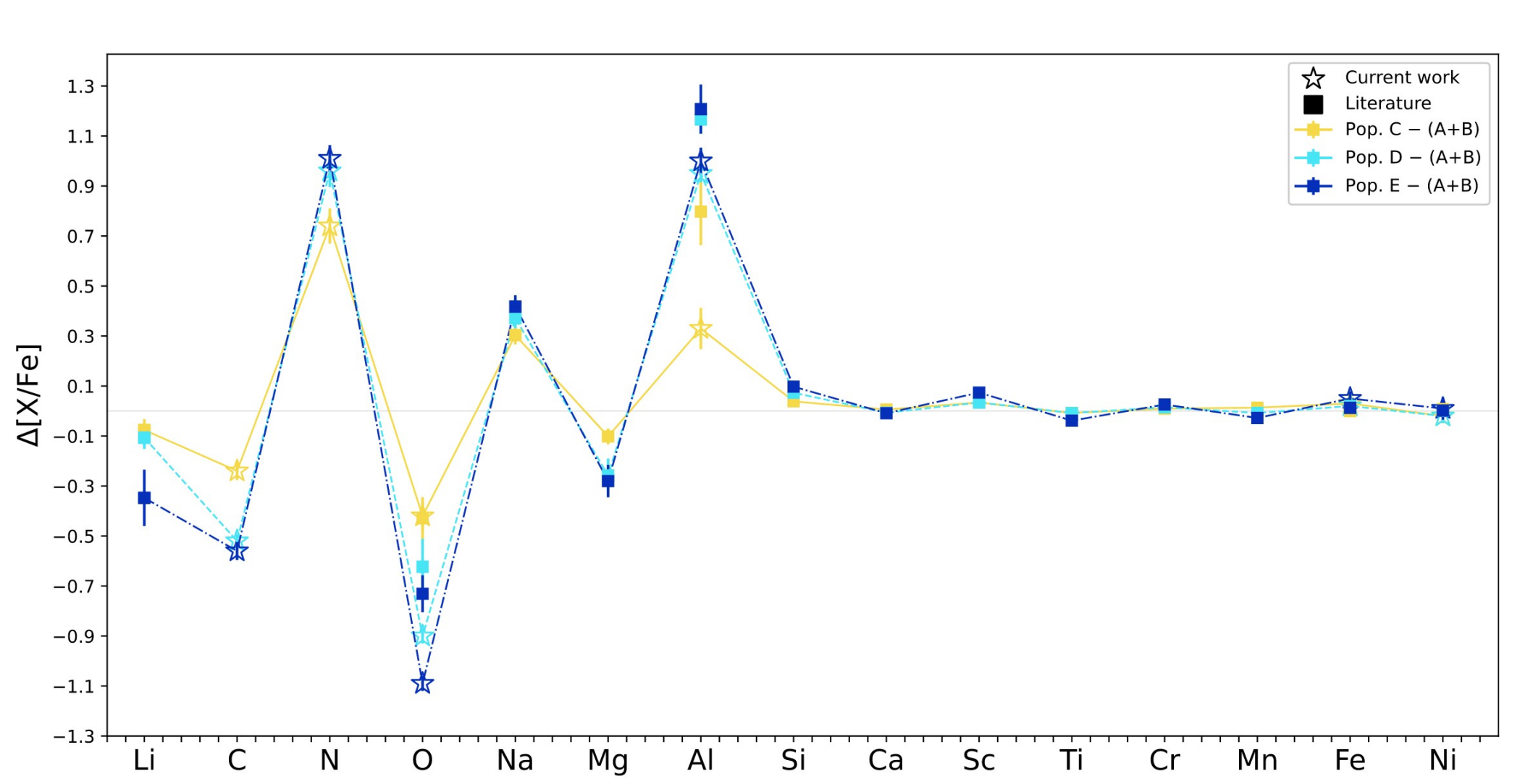

E
D
C
A+B
$\Delta_{CF275W,F336W,F438W}$
$\Delta_{F275W,F814W}$


E
D
C
A+B
$\Delta_{C\,U,B,I}$
$\Delta_{B,I}$

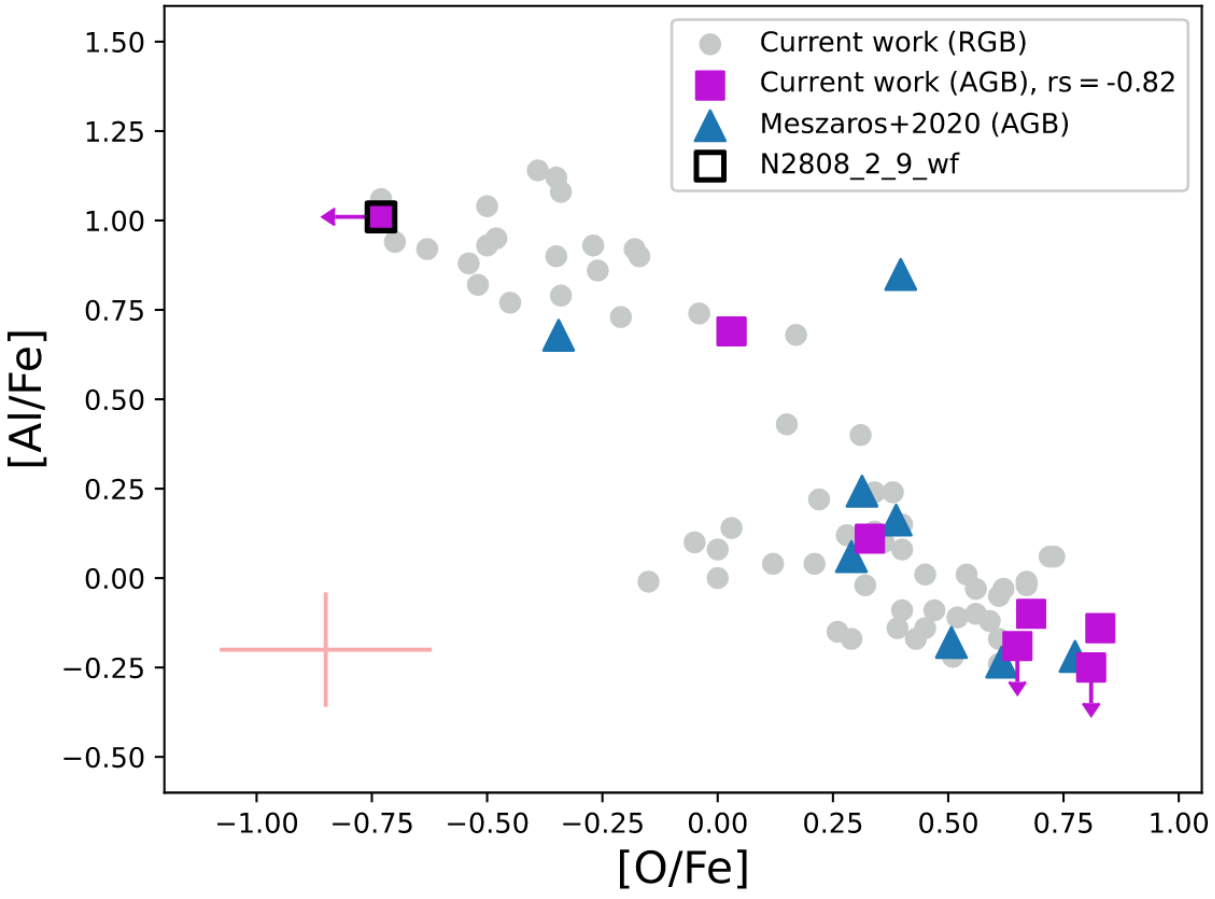

A(Li)
[Al/Fe]


[N/Fe]
[O/Fe]

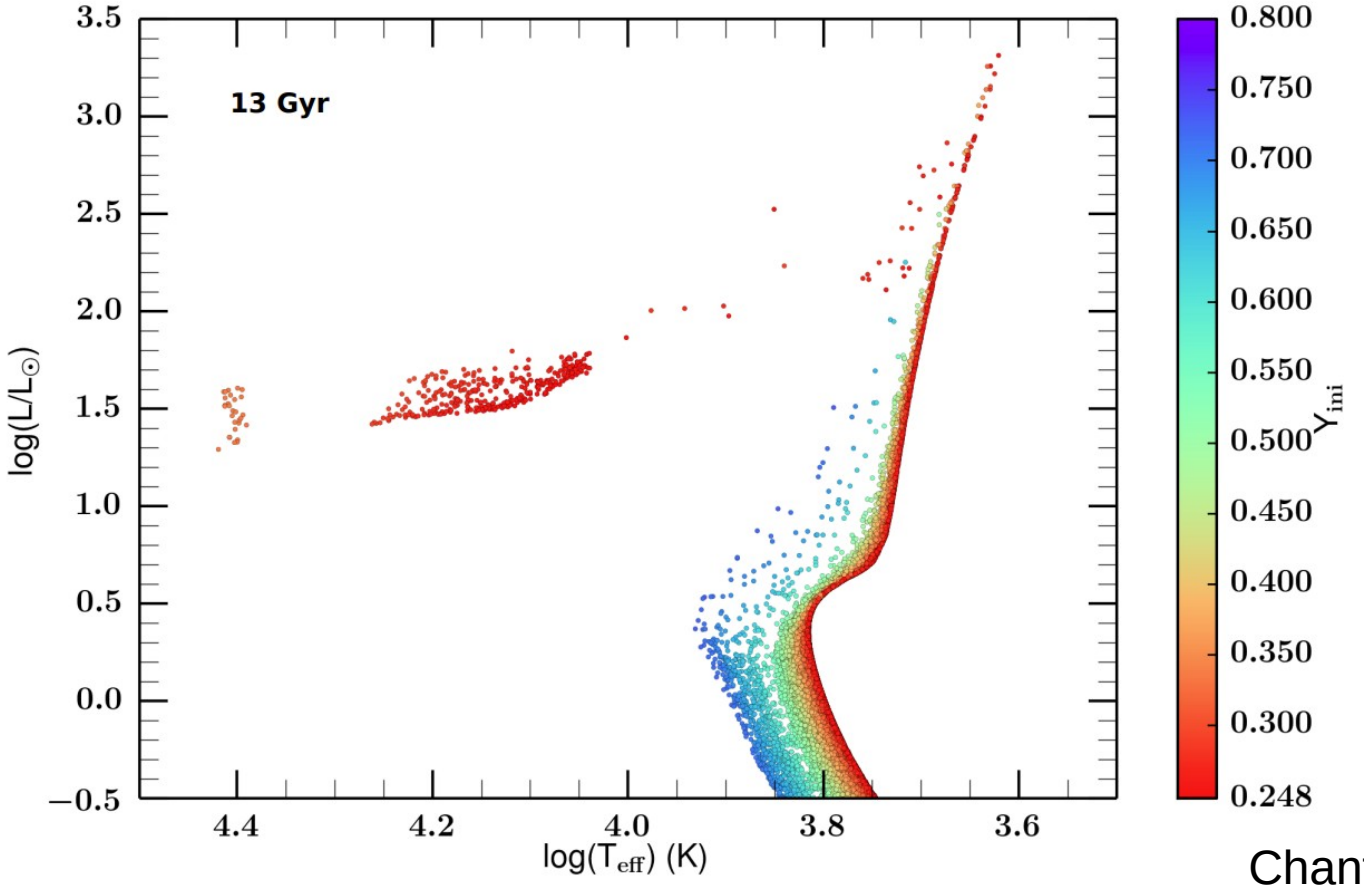

[Al/Fe]
[O/Fe]


Current work
Literature
Pop. C − (A+B)
Pop. D − (A+B)
Pop. E − (A+B)
Δ[X/Fe]
1.3
1.1
0.9
0.7
0.5
0.3
0.1
−0.1
−0.3
−0.5
−0.7
−0.9
−1.1
−1.3
Li
C
N
O
Na
Mg
Al
Si
Ca
Sc
Ti
Cr
Mn
Fe
Ni

AGB stars:


Current work (RGB)
Current work (AGB), rs = -0.82
Meszaros+2020 (AGB)
N2808_2_9_wf
[Al/Fe]
[O/Fe]
1.50
1.25
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−1.00
−0.75
−0.50
−0.25
0.00
0.25
0.50
0.75
1.00

AGB-manqué:



Chantereau+2016

Summary:

- GCs are very complex and variegated.
- We still lack a convincing scenario to explain their formation and evolution (none of the scenarios fully reproduce the observations).
- Combining information from ChMs and high precision abundances add valuable insight.
- Recent observations indicate that stars with high-He abundances can evolve into AGB (in contrast with some evolutionary models).