The role of cluster age on the onset of multiple populations in stellar clusters

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Traditional view of Globular Clusters

All the stars were thought to share the same age and chemical abundances.
GCs are not simple stellar populations

Piotto et al. 2007

NGC 2808

Milone et al. 2013

NGC 6752

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Multiple stellar populations (MPs)

Defined as star-to-star *light element abundance variations* within a given cluster.
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- N, Na, C, O, Mg, Al & more, with typical patterns
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- He varies as well
- C+N+O sum and [Fe/H] constant *in general*
- Not due to age differences (Nardiello et al. 2015, Martocchia et al. 2018)
Split Main Sequence
In clusters younger than 2 Gyr

NGC 1866, ~200 Myr, LMC
Milone et al. 2017

Extended Main Sequence Turnoff

NGC 1806, ~1.7 Gyr, LMC
Before starting...

Forget about these phenomena now. Multiple populations = star-to-star chemical anomalies *during this talk!*

NGC 1806, ~1.7 Gyr, LMC

NGC 1866, ~200 Myr, LMC

Milone et al. 2017
What controls the origin of MPs?

Compilation by Krause et al. 2013 (see ref. therein).
What controls the origin of MPs?

Ubiquity of MPs in ancient, massive clusters

Compilation by Krause et al. 2013 (see ref. therein)
What controls the origin of MPs?

NO MPs in “open”, less massive clusters

Berkeley 39
(Bragaglia et al. 2012)
What controls the origin of MPs?

Schiavon et al. 2013  Carretta et al. 2010  Milone et al. 2018
What controls the origin of MPs?

It is well established that **cluster mass** plays a role.

- Schiavon et al. 2013
- Carretta et al. 2010
- Milone et al. 2018

Fraction $\frac{FP}{(FP+SP)}$
What controls the origin of MPs?

Berkeley 39

(Bragaglia et al. 2012)
Our Surveys

1) HST photometric survey

13 clusters in the LMC/SMC
Ages = 1.5 – 10 Gyr
Masses >10^4Msun

New filters: F336W, F343N, F438W
Archival: F555W, F814W

The chosen filters pick up variations in N

Niederhofer et al. 2017a
Our Surveys

1) HST photometric survey
- 13 clusters in the LMC/SMC
- Ages = 1.5 – 10 Gyr
- Masses >10^4 M_{Sun}

2) ESO VLT spectroscopic survey (FORS2+XSHOOTER)
- 4 massive clusters in the SMC/LMC
- Ages = 2 - 8 Gyr

3) more clusters coming September 2019!!!
- Ages = 1.5-2 Gyr

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Results: MPs in 6-10 Gyr old clusters

Niederhofer et al. 2017a,b; Hollyhead et al. 2017, 2018
Results: NO MPs in 1.5-1.7 Gyr old clusters

Mucciarelli et al. 2008, 2014
Martocchia et al. 2017
Cabrera-Ziri et al. 2016
Lardo et al. 2017

NGC 1783
NGC 1806
NGC 419/NGC 1846
NGC 339
NGC 416
Lindsay 1
NGC 121

Mucciarelli et al. 2008, 2014
Martocchia et al. 2017
Cabrera-Ziri et al. 2016
Lardo et al. 2017

10/09/2019 Silvia Martocchia - Magellanic Clouds - ESO Garching
Results: NO MPs in 1.5-1.7 Gyr old clusters
MPs in ~2 to ~4 Gyr old clusters!!!!!!
MPs in \(~2\) to \(~4\) Gyr old clusters!!!!!!

\[ z \text{ of formation} \sim 0.17 \]
Cluster age and multiple populations

Take away (1):
The origin of MPs is **not** cosmological
Correlation between cluster age and abundance spreads

Proxy for Nitrogen spread

Martocchia et al. 2019

Martocchia et al. 2019

Cluster Age [Gyr]
Correlation between cluster age and abundance spreads

Take away (2):
Older clusters show larger abundance spreads compared to the younger ones

Martocchia et al. 2019
Age difference between the 2 stellar pops – NGC 1978

~2 Gyr old cluster
Take away (3): 

**Age difference <20 Myr !!**

Fundamental constraint for MPs formation scenarios
Summary and Conclusions

• Our main result shows that age may play a key role in the onset of multiple populations;

• For the first time MPs found in massive clusters down to 2 Gyr: formation mechanism
does not depend on redshift.

• The age difference between the 2 stellar populations in NGC 1978 is consistent with zero

• The origin of MPs is still debated. Future directions: exploration of parameters space +
  full characterisation of young clusters:
  He -> Chantereau+19, Lagioia+19
  Na, O, etc…
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Thank you!!!