

# Multiple Stellar Populations in Magellanic Clouds clusters

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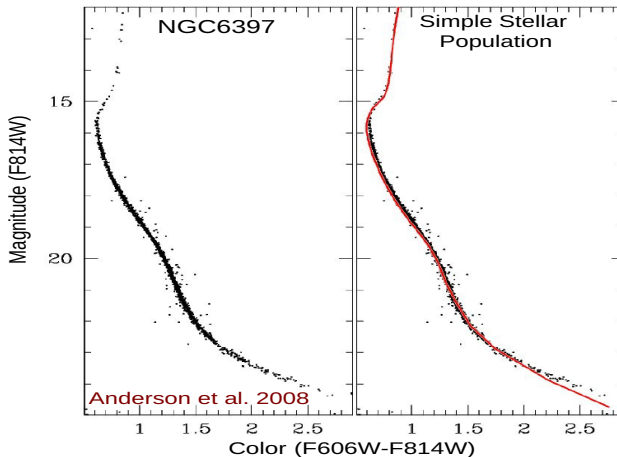
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# Old Galactic Globular Clusters a few years ago



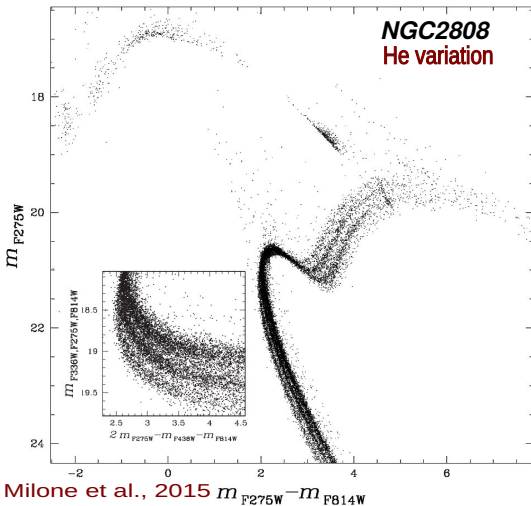
# Old Galactic Globular Clusters a few years ago

## Simple Stellar Population

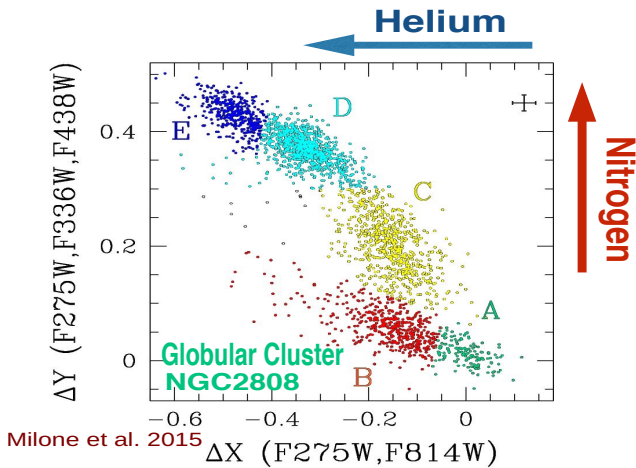
Globular Clusters were considered the prototypes of Simple Stellar Populations. All stars have

- same age
- same metallicity
- same Helium abundance

# Old Globular Clusters: state of the art



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## Multiple Stellar Populations

Old Globular clusters host Multiple Stellar Populations: two possible scenarios

- Multiple star formation episodes: 2<sup>nd</sup> generation of stars born out of the material polluted by 1<sup>st</sup> generation massive stars
- Coeval stellar populations : unknown physical mechanism

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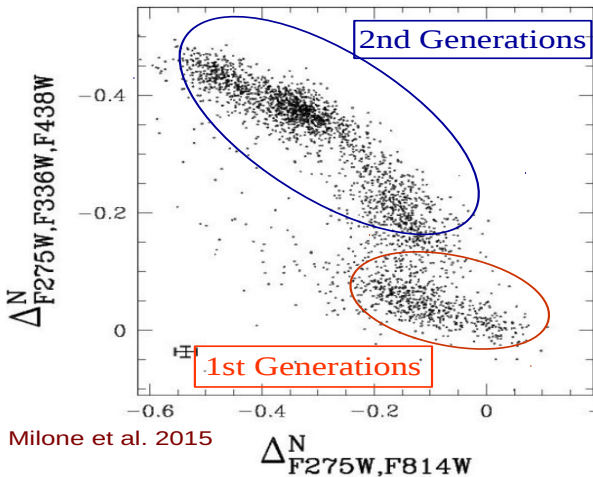
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# Implications



Milone et al. 2015

# Multipopulations importance

## Why study Multiple Populations

- *How did Globular Clusters form ?*
- *Which is their contribution to the mass of the Galactic Halo ?*
- *Which is their contribution to the Re-ionization ?*

**→ Understanding Multiple Populations may address these questions**

## But ...

Globular Clusters formed  $\sim 13$  Gyr ago ...

It is challenging to understand the mechanisms responsible for the formation of multipopulations in Globular Clusters

**→ We need younger objects !!**

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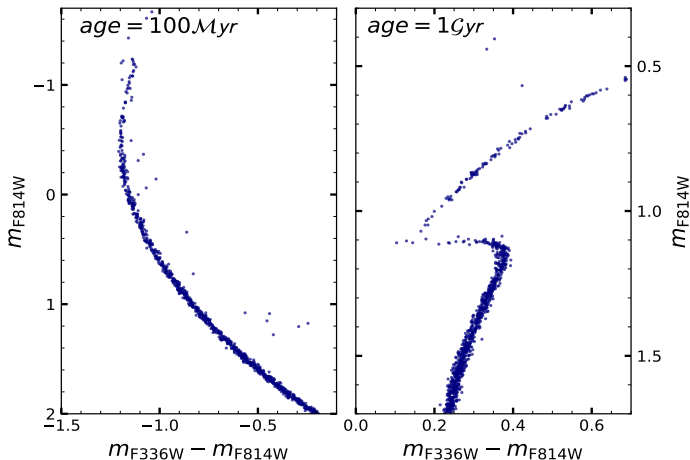
# Magellanic Clouds Clusters



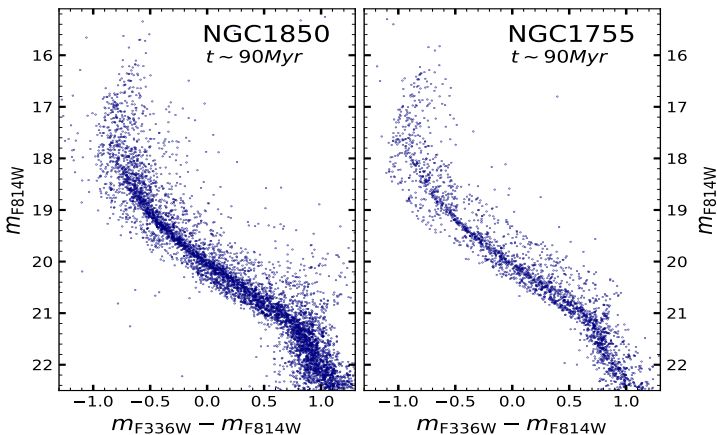
## “Young” Clusters

Globular Clusters in the Magellanic Clouds span a wide age range. Young  $< 1\text{Gyr}$  and Intermediate-age (1-2Gyr) Globular Clusters in the Magellanic Clouds may help us finding the answers

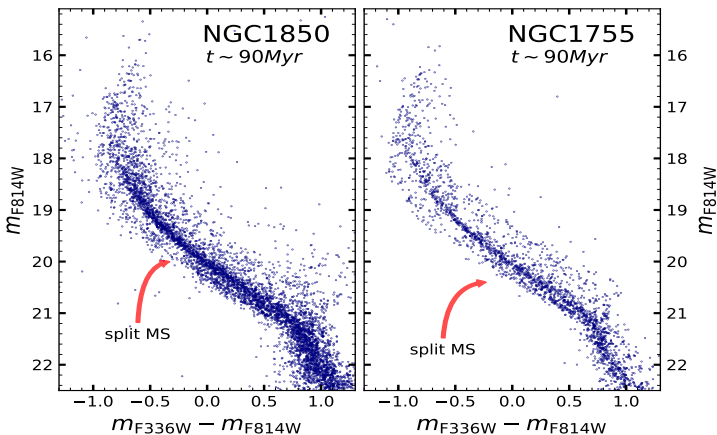
# Synthetic CMDs of Simple Stellar Populations



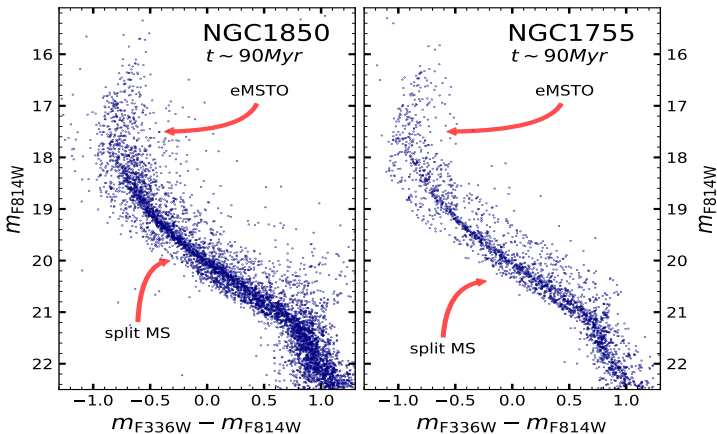
# Observed CMDs of Young Clusters



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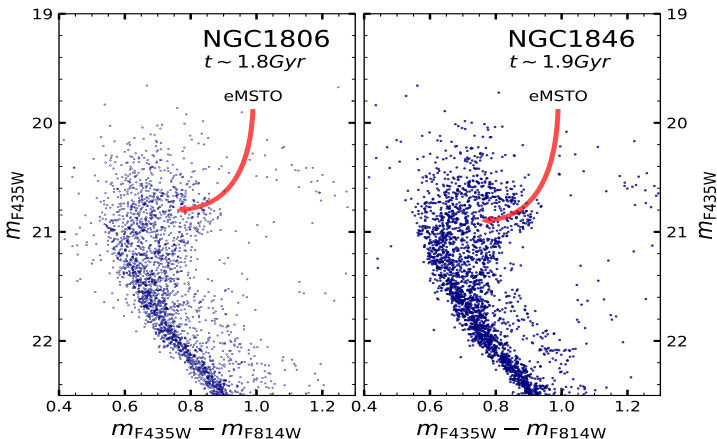


# Observed CMDs of Young Clusters





# Observed CMDs of Intermediate-age Clusters

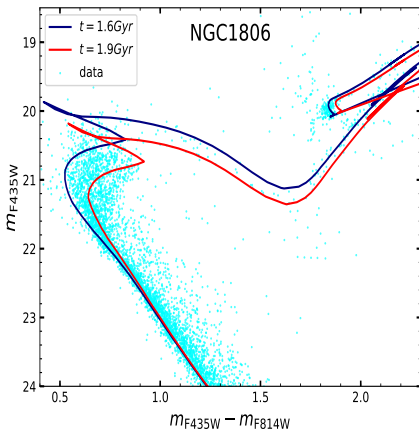


# Interpretation of the complex CMDs

## Big issues

- *Where do these features come from?*
- *Are there Multiple Populations in Magellanic Clouds clusters?*
- *Are Young Clusters the younger counterpart of Old Globular Clusters?*

# Magellanic Clouds Clusters



## Multiple Stellar Generations

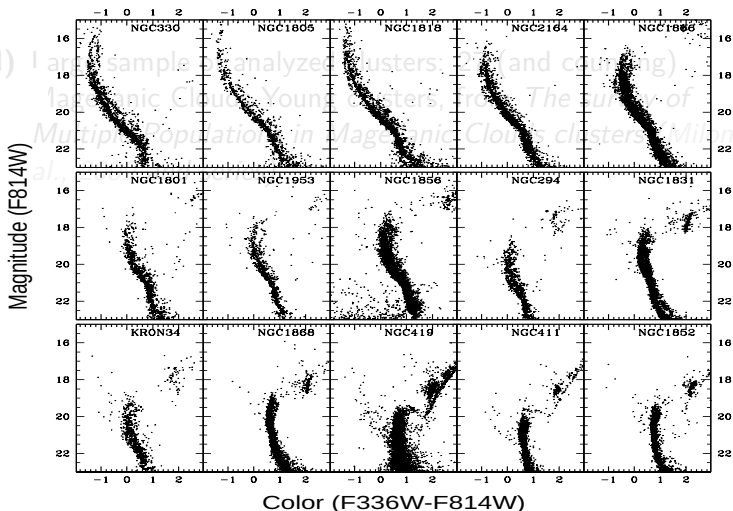
Young and Intermediate-age Magellanic Clouds clusters host Multiple Stellar Generations with different age.

→ The eMSTO is due to stars with different age !!!

# Age Spread in Magellanic Clouds Clusters

- I) Large sample of analyzed clusters: 27 (and counting)  
Magellanic Clouds Young clusters, from *The survey of Multiple Populations in Magellanic Clouds clusters (Milone et al., 2009 and series)*.

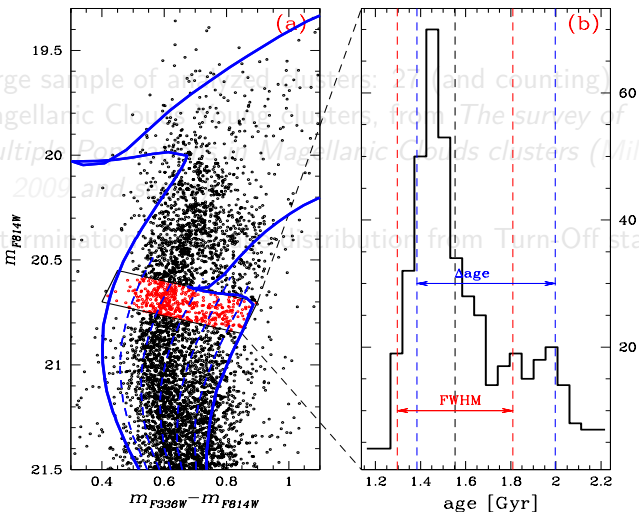
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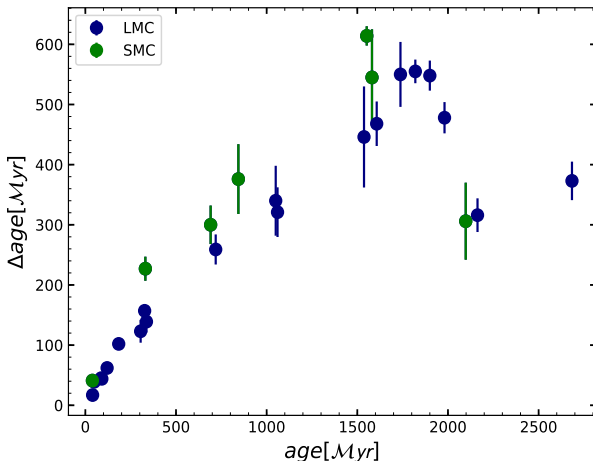
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- II) Determination of the age distribution from Turn-Off stars
- III) Build-up of the *Delta age vs. Age* relation



# Age Spread in Magellanic Clouds Clusters

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II) D  
III) B



## Challenge

Multiple star formation episodes are unlikely to reproduce the observed trend !!

Other physical mechanisms must be responsible for the observed spread

**Which mechanisms?**

## Rotation

- *What about rotation?*
- *What if these clusters host coeval stellar populations with different rotation velocities?*

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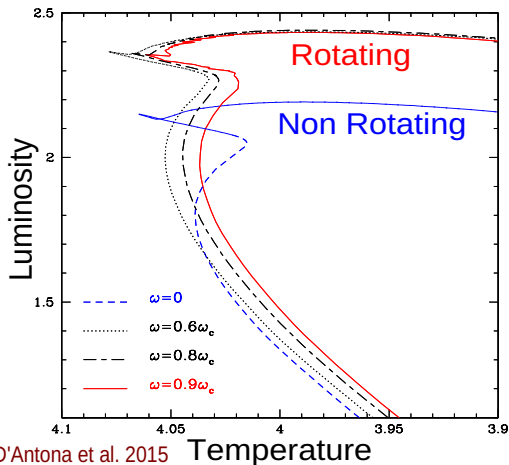
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# Effects of *Rotation*

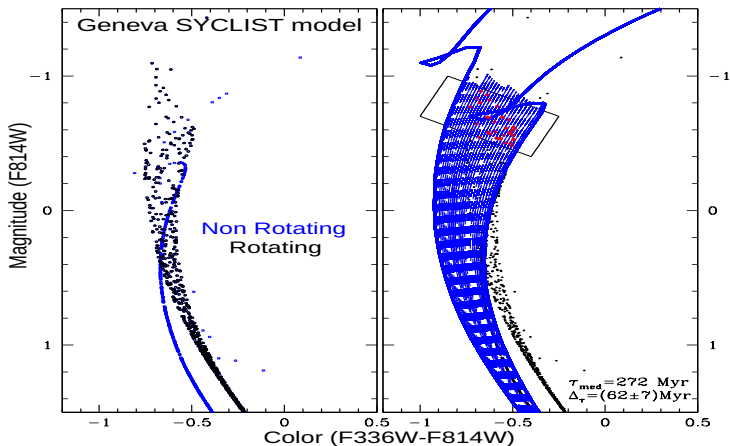


# Model analysis

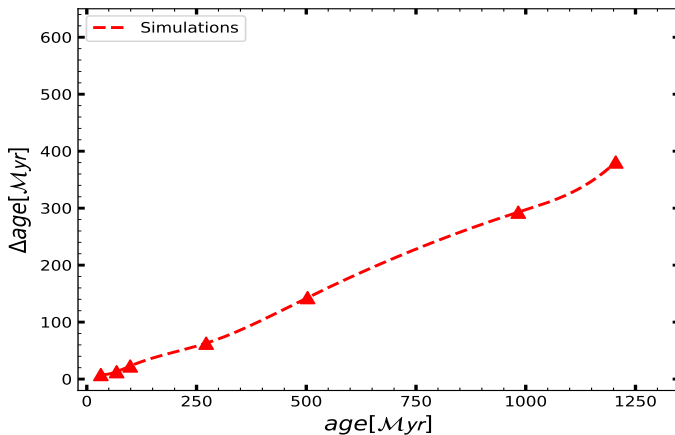
## What if ...

... the Turn-Off spread in the simulation of a cluster with coeval stellar populations with different rotation rates is interpreted as a physical age spread ?

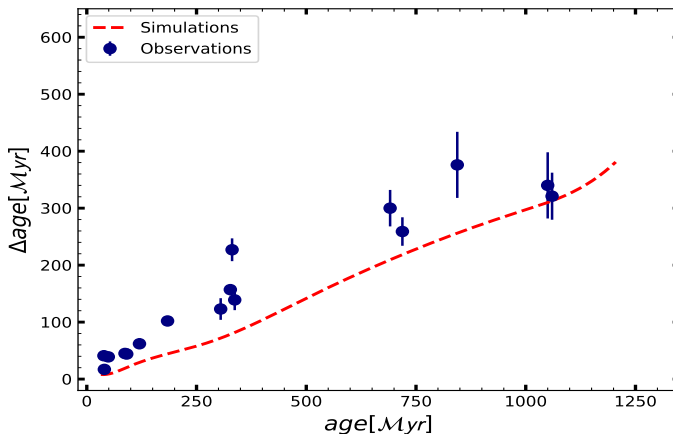
# Model analysis



# Rotational relation

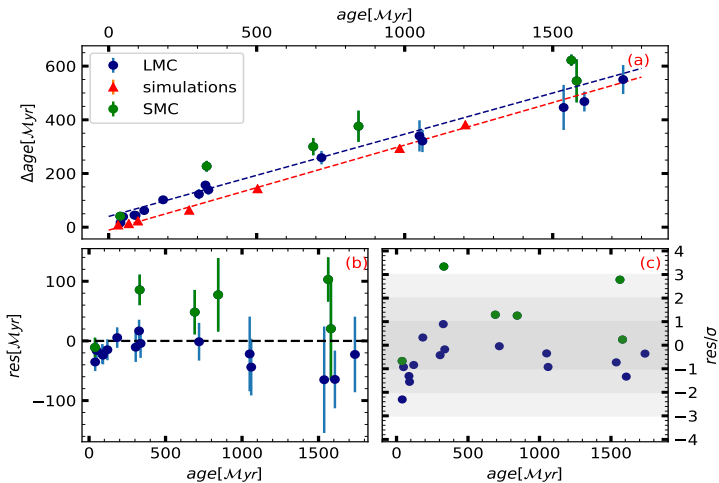


# Comparison with observations





# Residual Age Spread



# Conclusions

## Facts

- Young GCs host coeval populations with different rotation velocity
- Rotation is responsible for the eMSTO in the CMDs
- Multiple populations of Young and Old GCs are likely due to different phenomena

## Open questions

- *How did these objects form?*
- *Did stars form with the same rotation velocity? If so, did they brake?*
- *Which physical mechanism is responsible for the braking process?*