

Multiple Stellar Populations in Magellanic Clouds clusters

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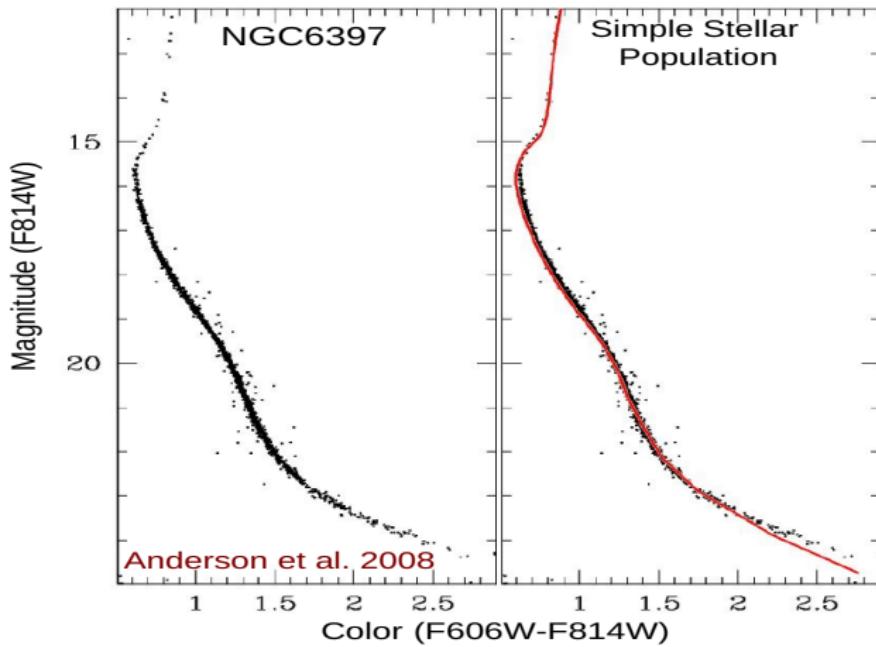
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<http://progetti.dfa.unipd.it/GALFOR/>



Old Galactic Globular Clusters a few years ago



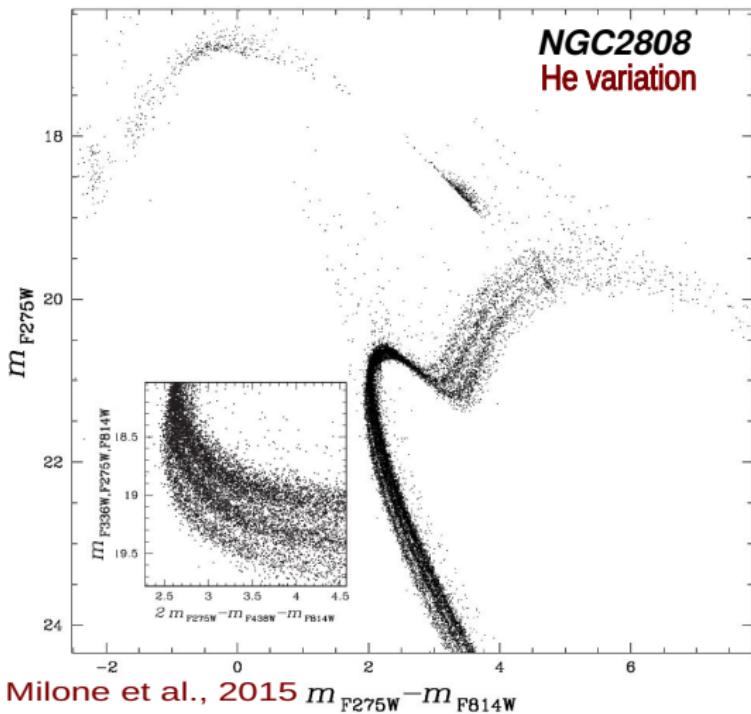
Old Galactic Globular Clusters a few years ago

Simple Stellar Population

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

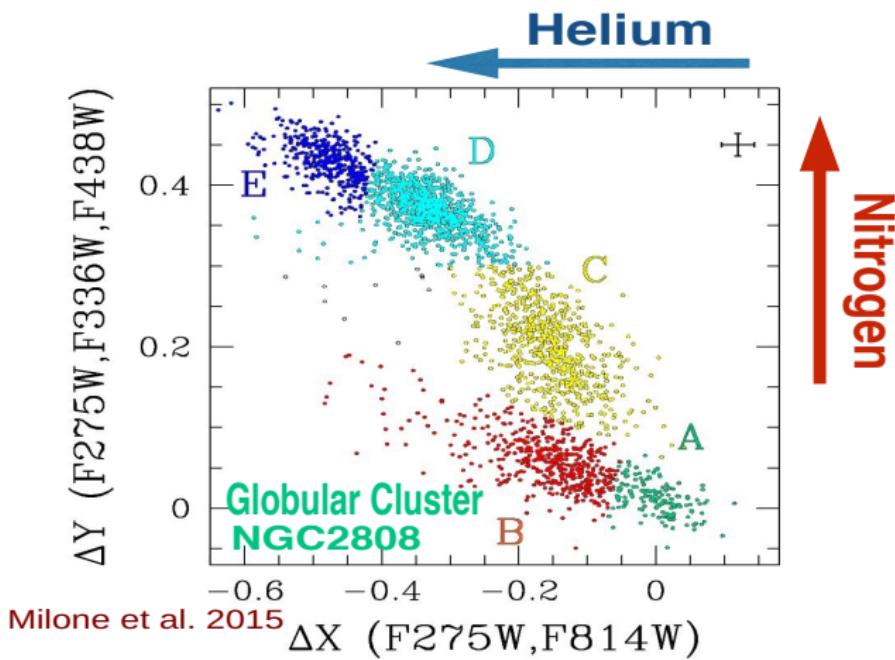
- same age
- same metallicity
- same Helium abundance

Old Globular Clusters: state of the art



Milone et al., 2015 $m_{\text{F275W}} - m_{\text{F814W}}$

Old Globular Clusters: state of the art



Old Globular Clusters: state of the art

Multiple Stellar Populations

Old Globular clusters host Multiple Stellar Populations: two possible scenarios

- Multiple star formation episodes: 2^{nd} generation of stars born out of the material polluted by 1^{st} generation massive stars
- Coeval stellar populations : unknown physical mechanism

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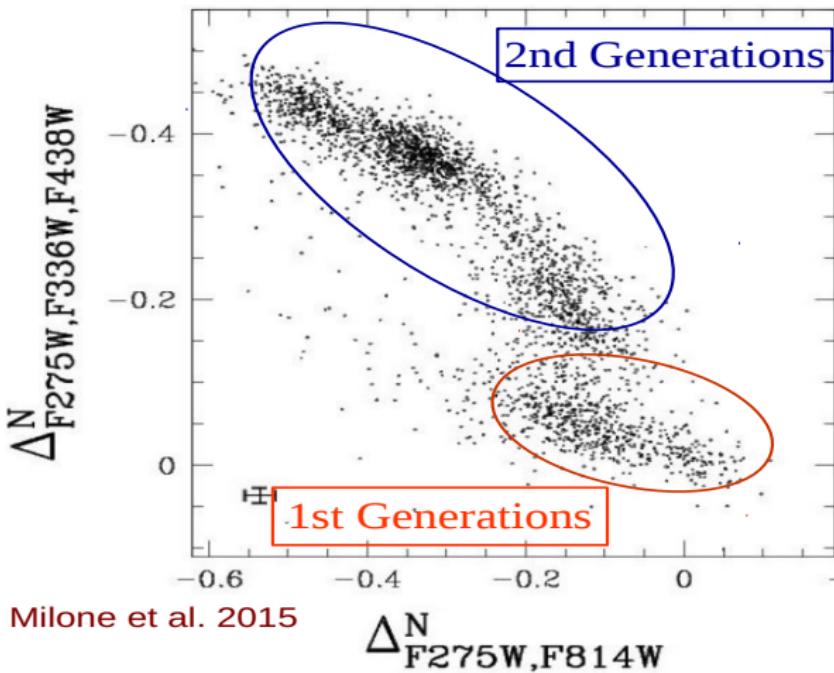
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Implications



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 ~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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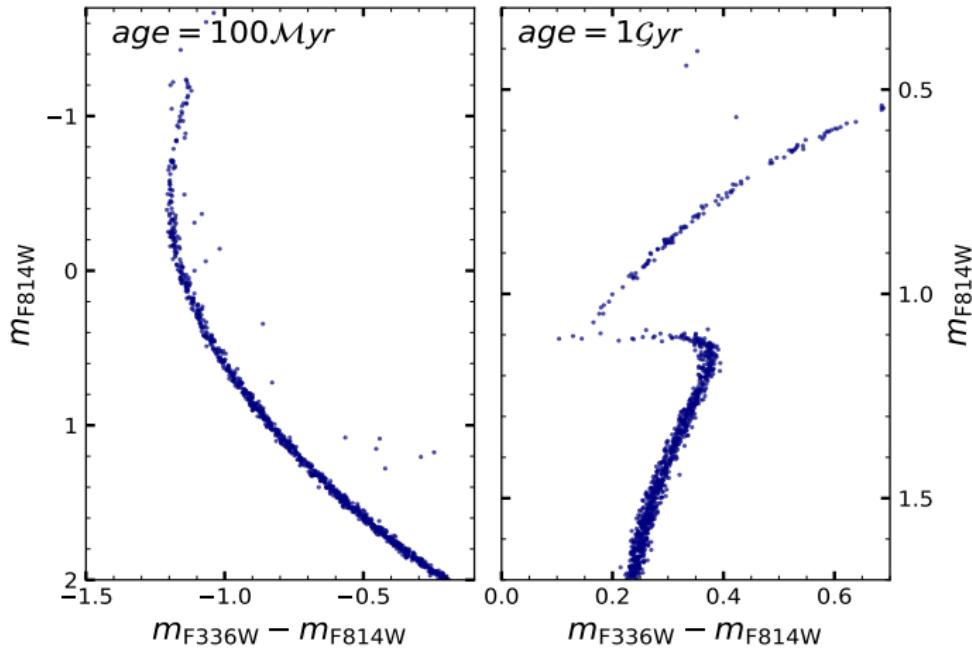
Magellanic Clouds Clusters



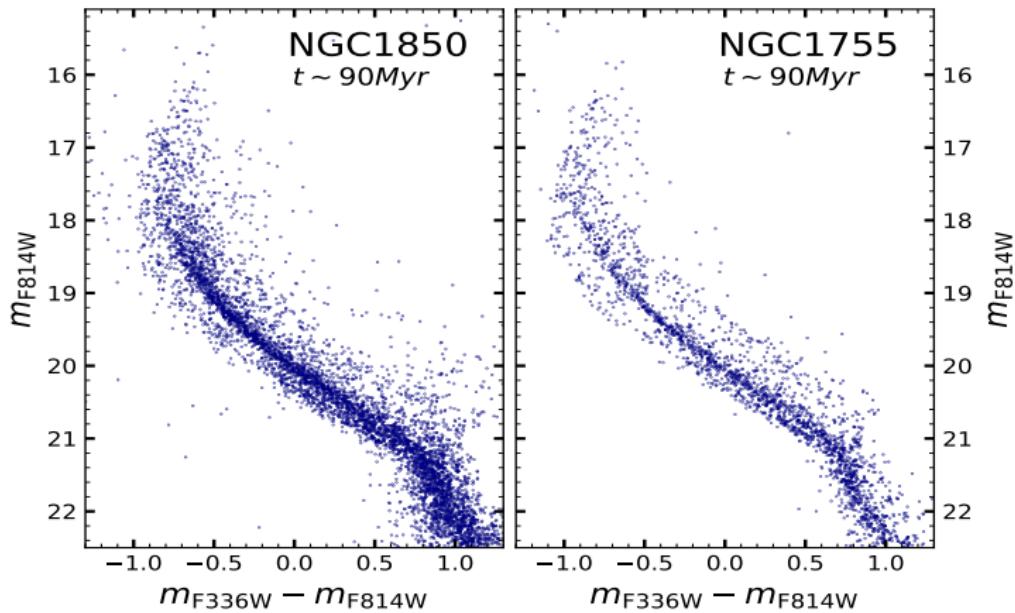
“Young” Clusters

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

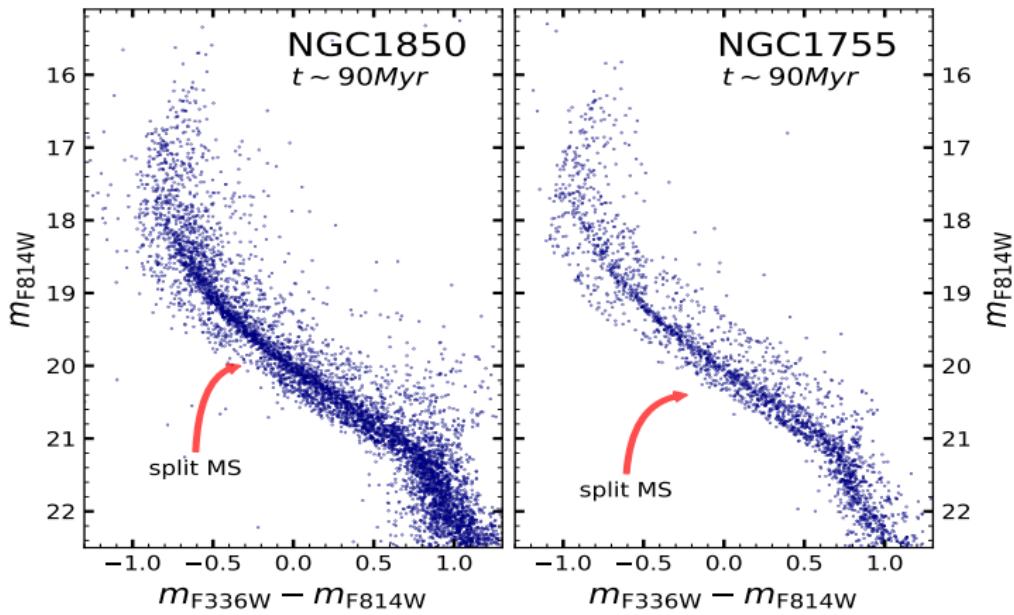
Synthetic CMDs of Simple Stellar Populations



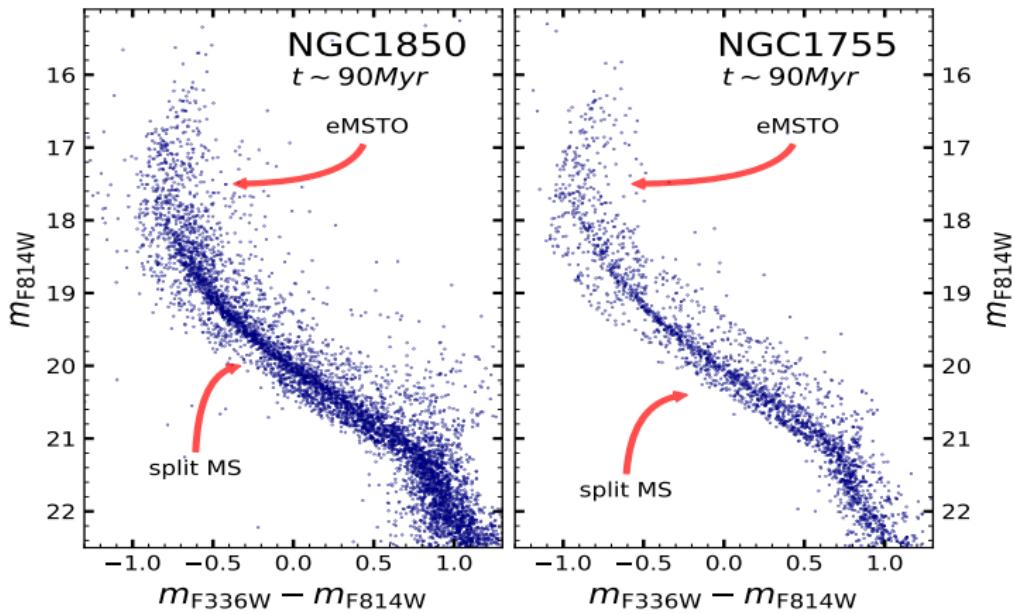
Observed CMDs of Young Clusters



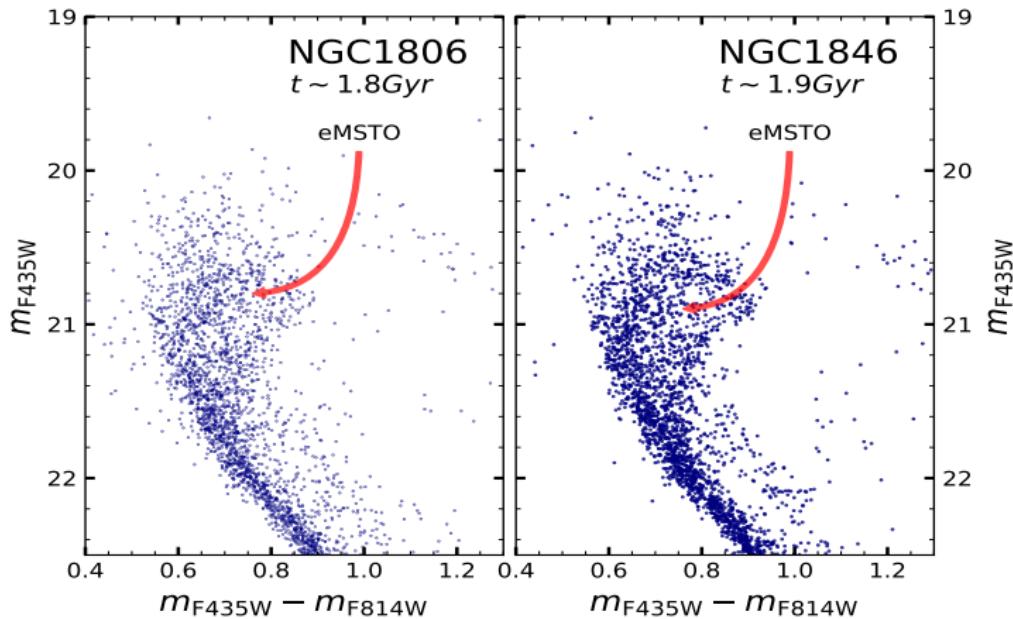
Observed CMDs of Young Clusters



Observed CMDs of Young Clusters



Observed CMDs of Intermediate-age Clusters

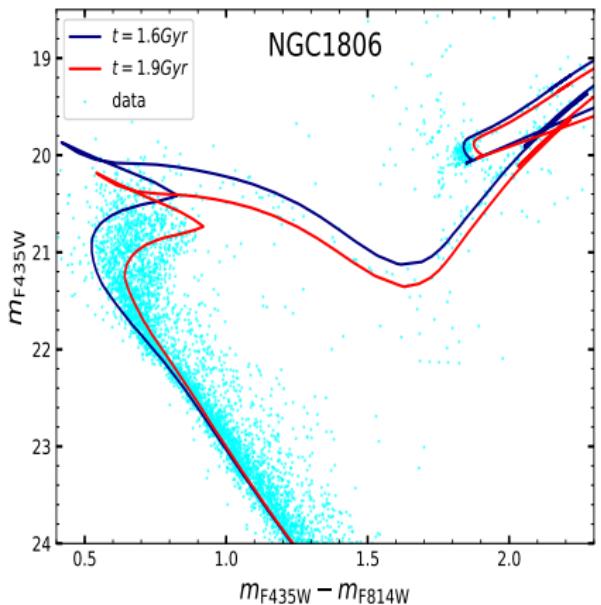


Interpretation of the complex CMDs

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.

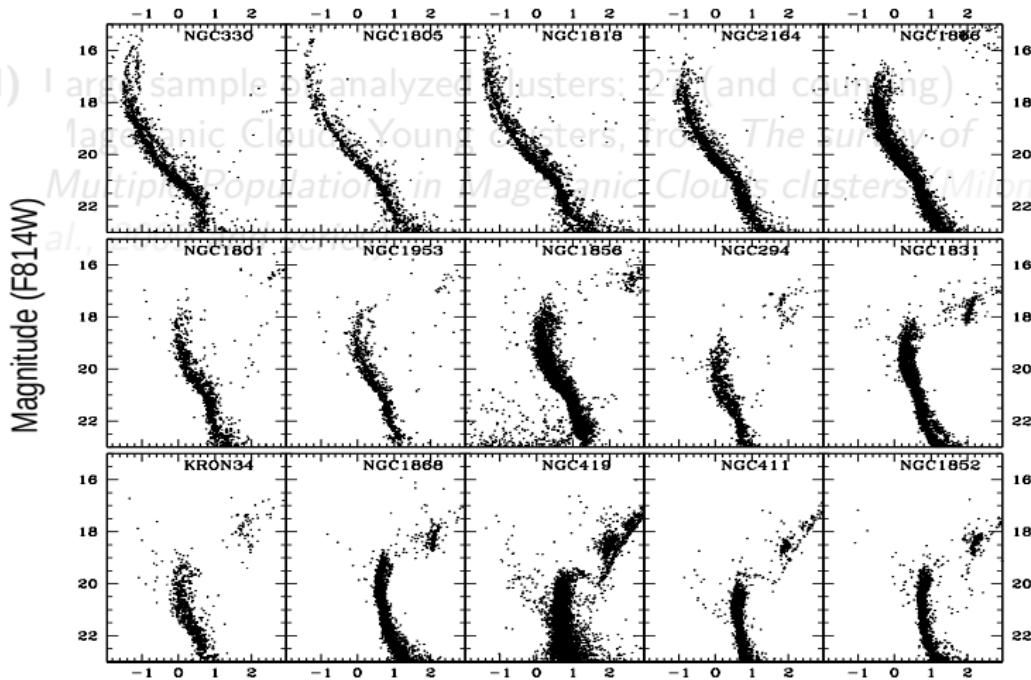
→ The eMSTO is due to stars with different age !!!

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)*.

Age Spread in Magellanic Clouds Clusters

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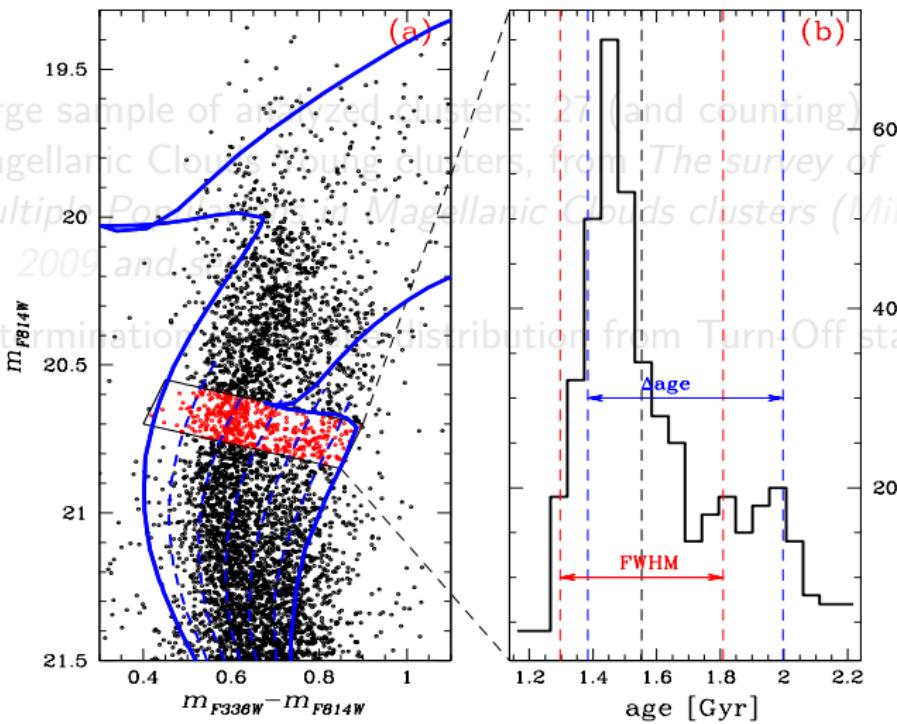
Color (F336W-F814W)

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)*.
- II) Determination of the age distribution from Turn-Off stars

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- II) Determination of age distribution from Turn-Off stars



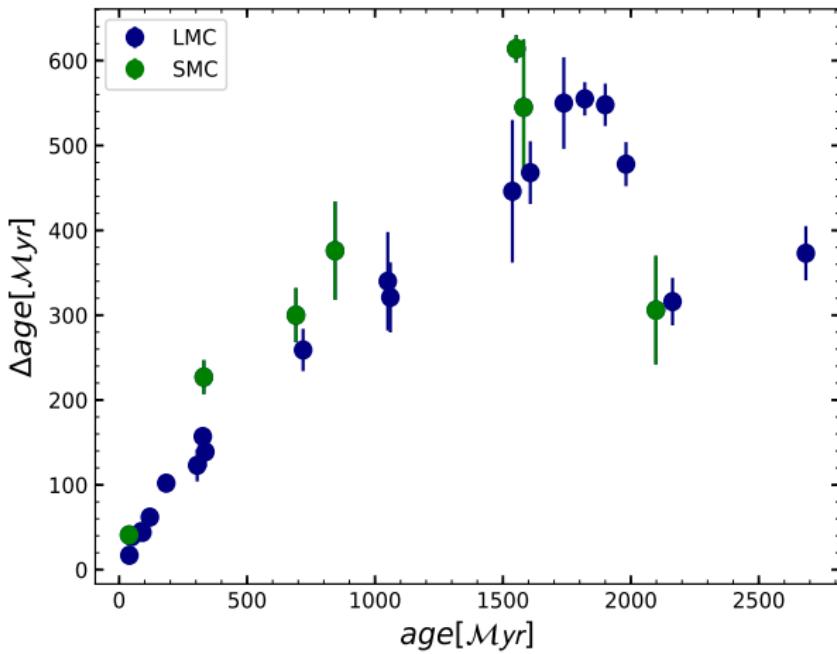
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- II) Determination of the age distribution from Turn-Off stars
- III) Build-up of the *Delta age vs. Age* relation

Age Spread in Magellanic Clouds Clusters

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III) B

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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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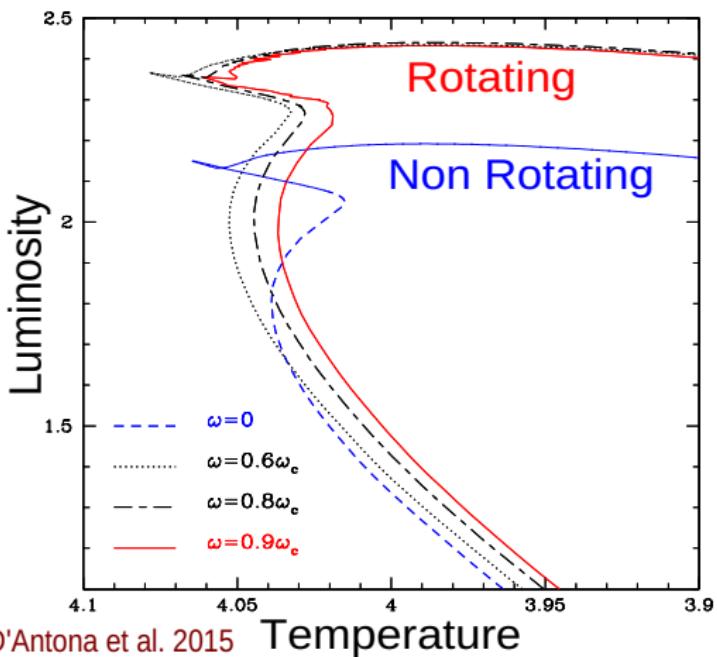
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Rotation scenario

Effects of *Rotation*



D'Antona et al. 2015

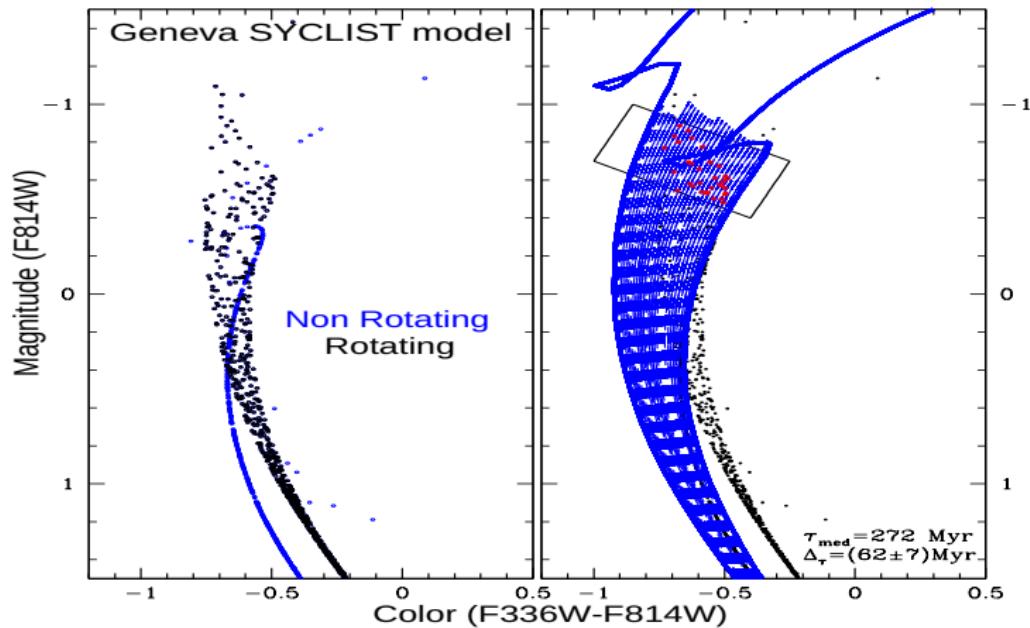
Model analysis

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 ?

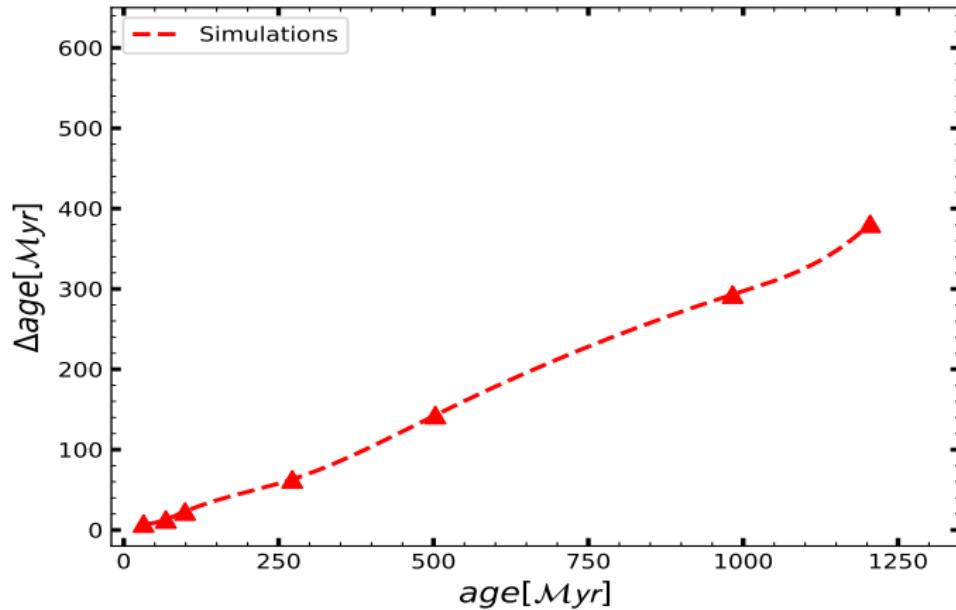
Rotation scenario

Model analysis



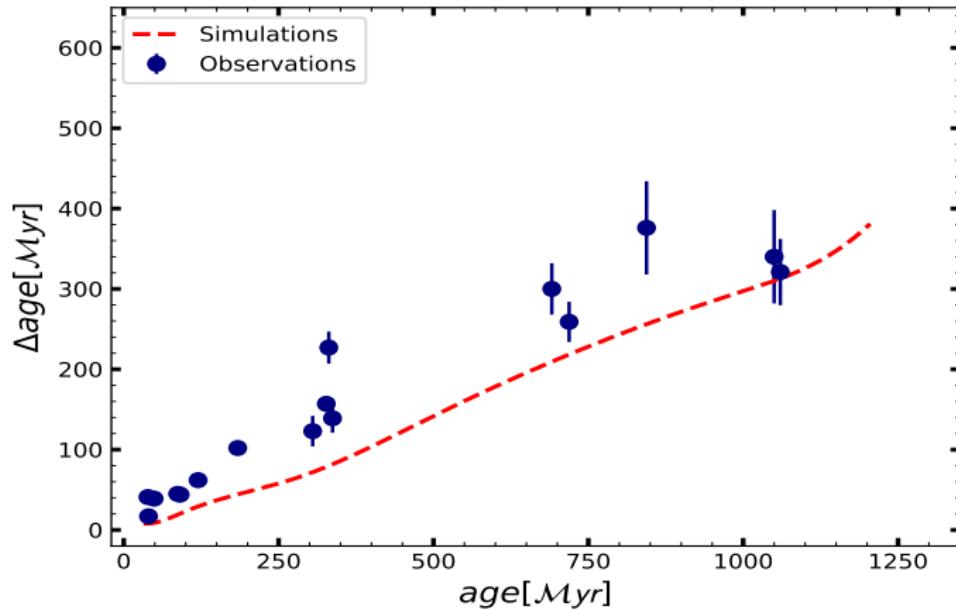
Rotation scenario

Rotational relation



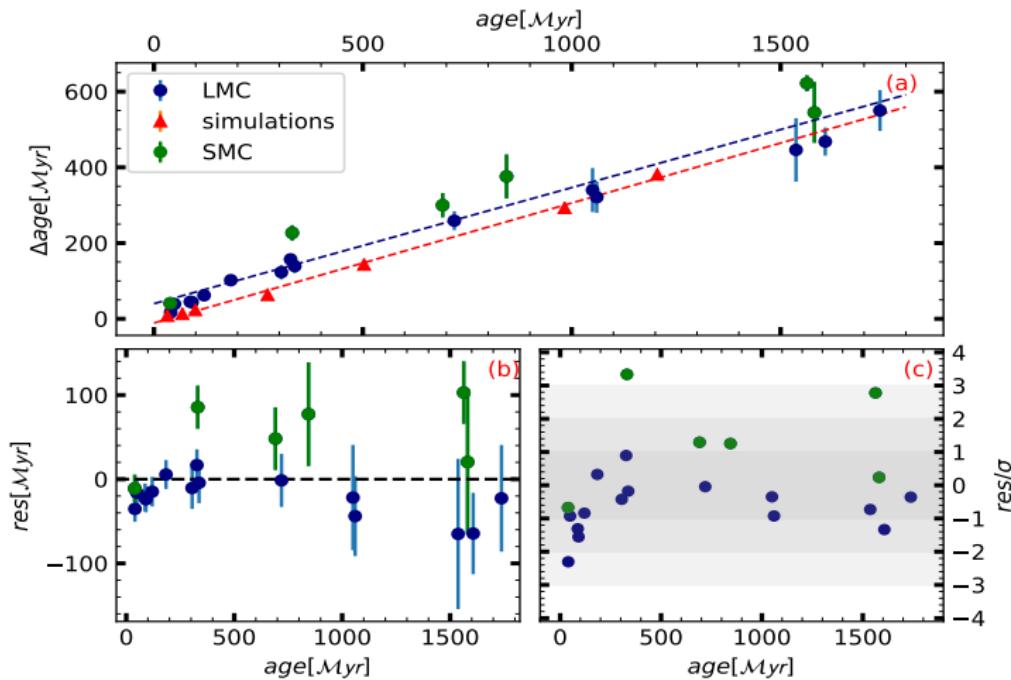
Rotation scenario

Comparison with observations



Rotation scenario

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?*