Mass loss of different stellar populations in globular clusters

Marco Tailo
Explore the problem of the parameter degeneracy on the Horizontal Branch

Explain how we can break it

Discuss some implications
The position of a star on the HB
The position of a star on the HB

From Piotto et al. (2015) data
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The Horizontal Branch is the locus of the **helium burning stars**

These stars have always played a **central role** in the study of Globular Clusters

Horizontal branch stars are the product of the **helium flash** at the Red Giant Branch tip.

From Piotto et al. (2015) data
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Active He core

Envelope with an active H shell

The less massive the HB star, the less extended the envelope, the bluer it is.
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Second parameter problem

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Second parameter problem

Clusters with similar age and metallicity show different HBs

In spite of decades of study there are still many other problems to be solved.

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The position of a star on the HB

Four main parameters: **Age**, **Metallicity** (here as \([\text{Fe/H}]\)), **helium content** \((Y)\) and **mass loss** (regulating the envelope mass).

Age and Metallicity can be evaluated from independent sources. Helium and mass loss **usually not**.
The position of a star on the HB

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The position of a star on the HB

Multiple combination of helium (Y) and mass loss produce the same HB stars

[Fe/H] = -1.44   Age= 12Gyr

Y = 0.25; $M_{\text{loss}} = 0.22 M_{\odot}$

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We need a way to break this parameter degeneracy!

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Breaking the degeneracy

If only we could separate the populations in a GC AND measure the helium abundance…..
Breaking the degeneracy

WAIT!
We can identify the populations via the chromosome map!

Milone et al. 2015,2017,2018; Lagioia 2018
Breaking the degeneracy

With the populations identified we can measure the colour difference between them!

First Generation
Second Generation

Milone et al. 2015, 2017, 2018; Lagioia 2018
Breaking the degeneracy

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What if we try to apply this to the simplest cluster there is?
M4: an ideal target

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Simple: **two populations well identified** in all evolutionary phases

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Well constrained: we have **strong indication** on the nature of the HB stars

The helium enhancement in M4

We can identify the two populations of stars down to the Main Sequence.

Tailo et al. 2019
The helium enhancement in M4

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$$\Delta Y = 0.013 \pm 0.002$$

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This is independent from the HB morphology and the second generation formation scenario!

Tailo et al. 2019
HB simulations!

We can now start simulating the HB with a new constraint!

Tailo et al. 2019
HB simulations!

We know from spectroscopy that all the first generation stars populate the red HB.

Tailo et al. 2019
HB simulations!

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We needed to **increase** the mass loss of the second generation by about 15%.
HB simulations!

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The amount of additional mass loss needed (~15%) is too high to be exclusively due to the structural differences in the stars alone. In either cases we are in uncharted territory!

Mass loss rate in the pre-HB stages could depend on helium.

Formation environment influence the mass loss in second generation stars.

Tailo et al. 2015, 2019
Conclusions

Second generation stars need to lose more mass in the pre-HB phases.

What we found in M4 suggests that this can not be due to stellar structure differences, alone.

We suggest a link to new mass loss physics or to unknown connection with the formation environment and scenario.

Still a lot of work to do!

Thank you!