



OLD STELLAR SYSTEMS IN UV: RESOLVED AND INTEGRATED PROPERTIES

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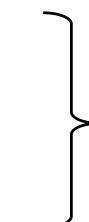


- ◆ 5-year project
- ◆ *Advanced Research Grant* funded by the European Research Council (ERC)
- ◆ PI: Francesco R. Ferraro (Dip. of Physics & Astronomy – Bologna University)
- ◆ AIM: **to understand the complex interplay between dynamics & stellar evolution**
- ◆ HOW: using **globular clusters** as cosmic laboratories and

Blue Straggler Stars

Millisecond Pulsars

Intermediate-mass Black Holes



as probe-particles



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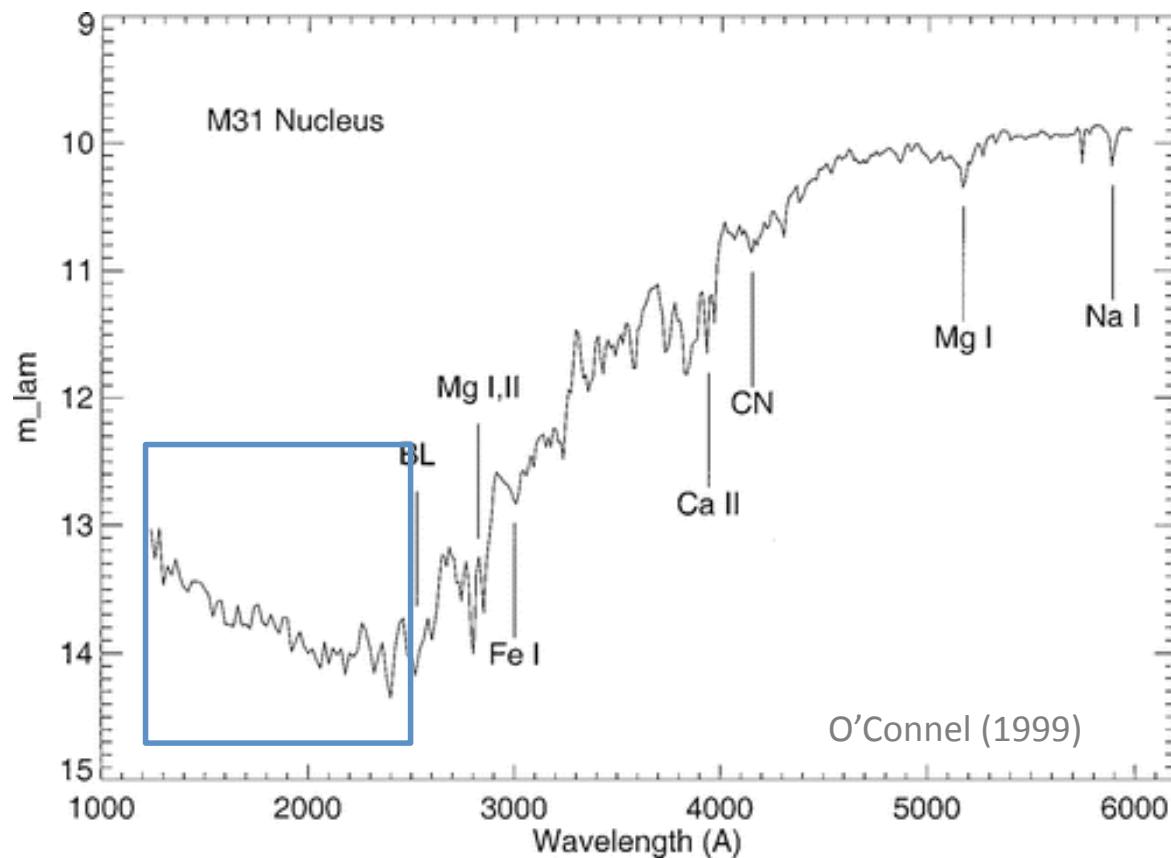
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Old Stellar Populations in UV

The UV upturn

Understanding the origin and the frequency of hot stars is not simply a problem of understanding the evolution of old, low mass stars. It has important implication on the interpretation spectra of galaxies.



Hot stars have been suggested to be responsible of the UV upturn in the spectrum of elliptical galaxies and bulges
(Greggio & Renzini 1990)

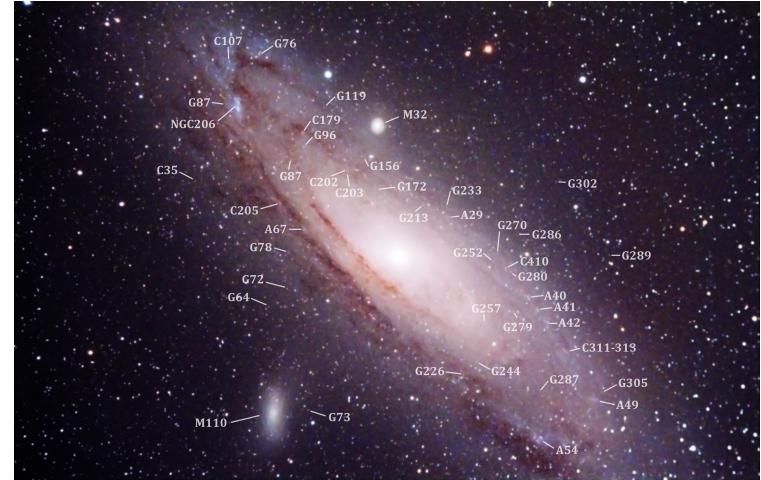


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GGCs are the best laboratory



Detailed knowledge of the underlying stellar population



Integrated properties

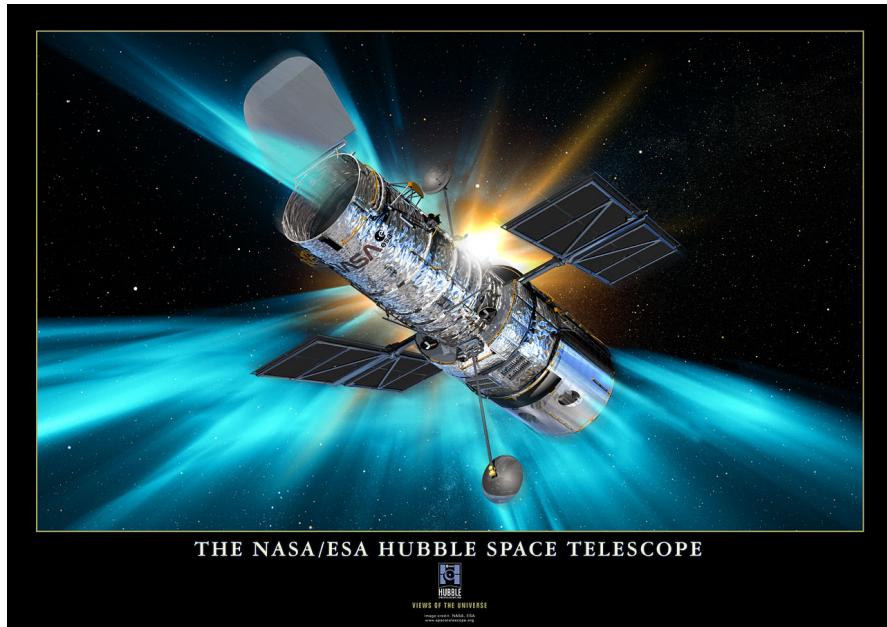


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HST + GALEX: the best tool



HST-WFPC2 UV SURVEY

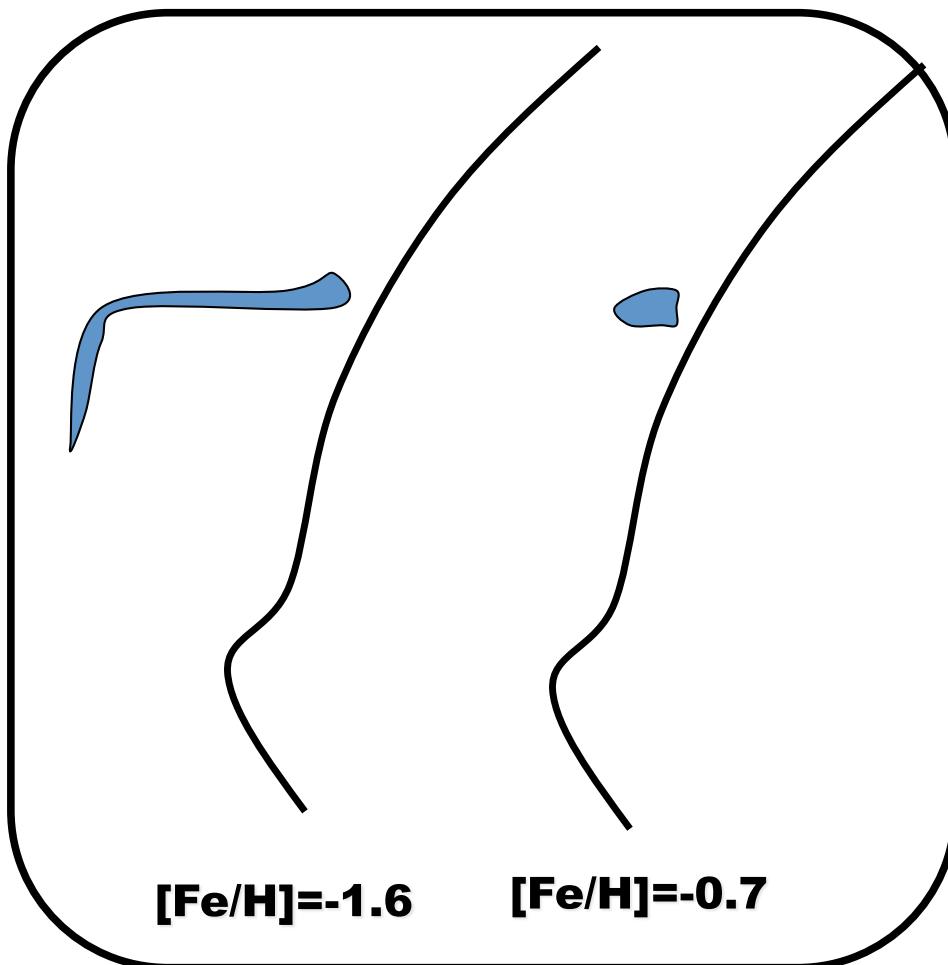
- Prop: GO-11975 – PI: Ferraro
- more than 35 GCs

GALEX SURVEY of GGCs

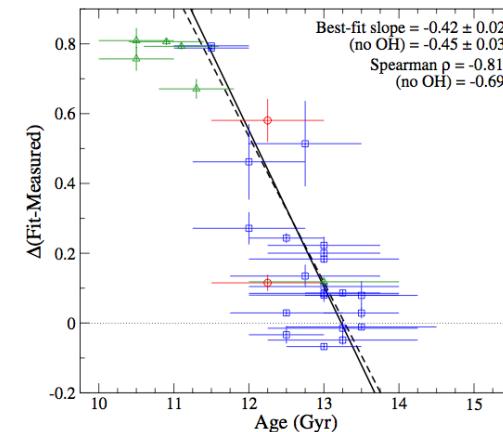
- PI: Schiavon
- 44 GGCs in both FUV and NUV

The Horizontal Branch

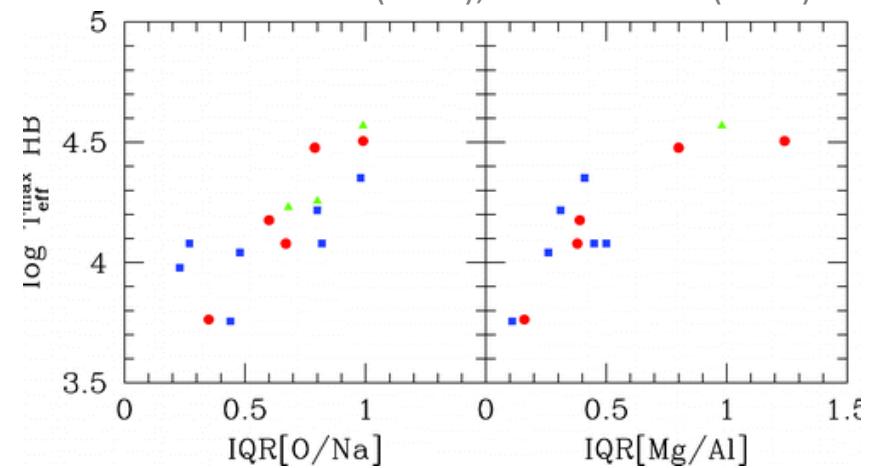
Metallicity is the first parameter



Age is the second
Lee et al. (1194); Dotter et al. (2010);
Gratton et al. (2010)

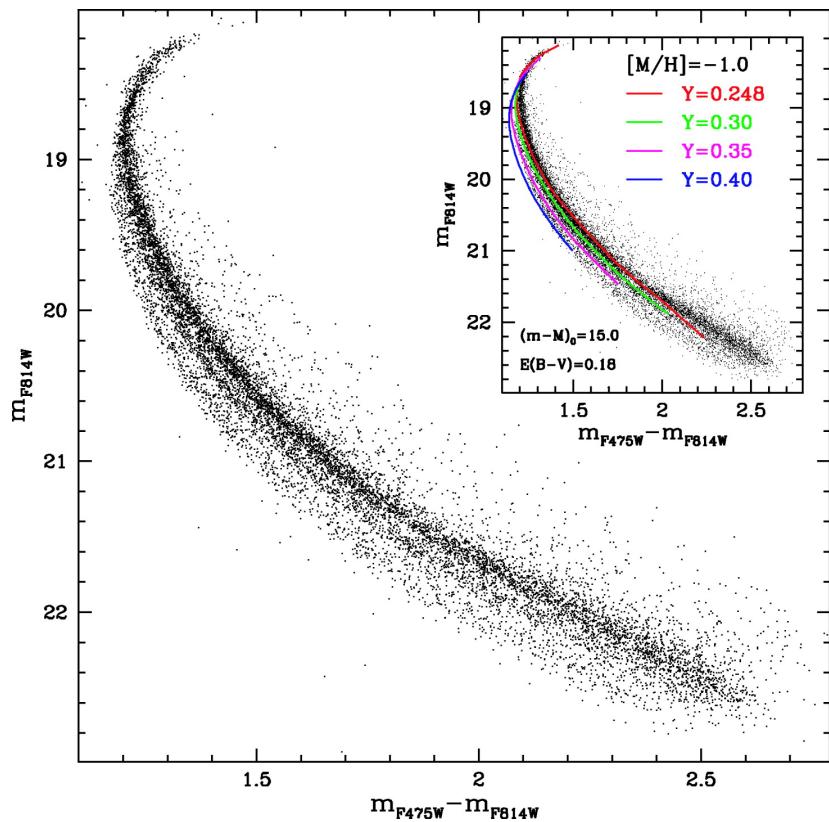


Chemical anomalies also?
Carretta et al. (2007); Gratton et al. (2011)

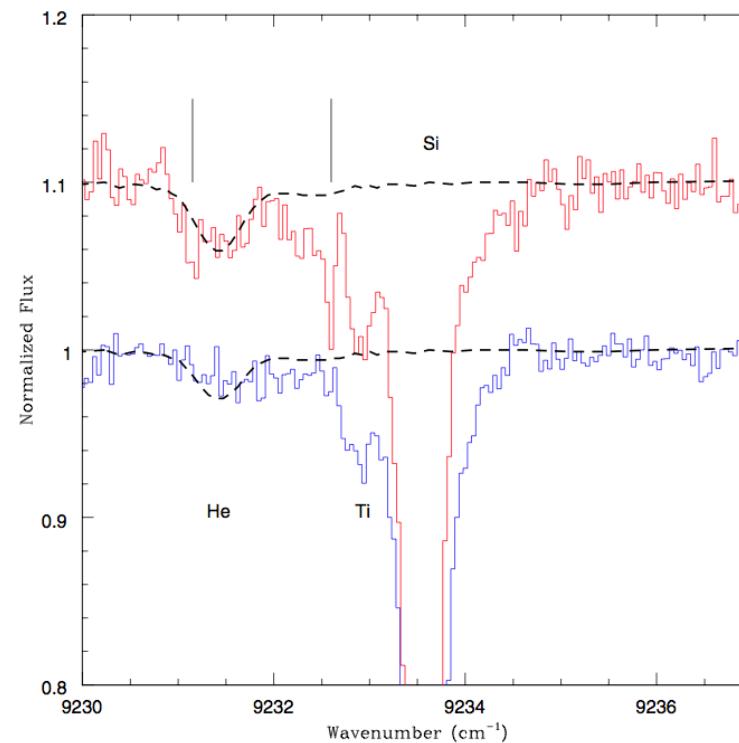


RESOLVED PROPERTIES WITH HST

The Horizontal Branch in UV: NGC 2808

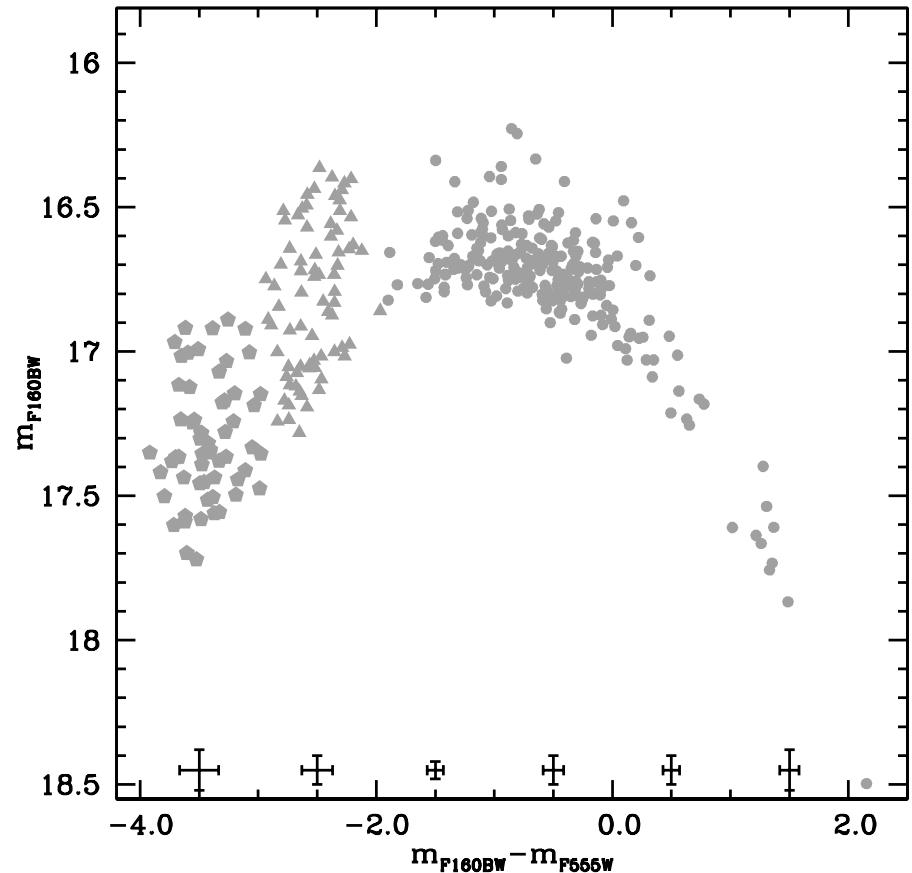
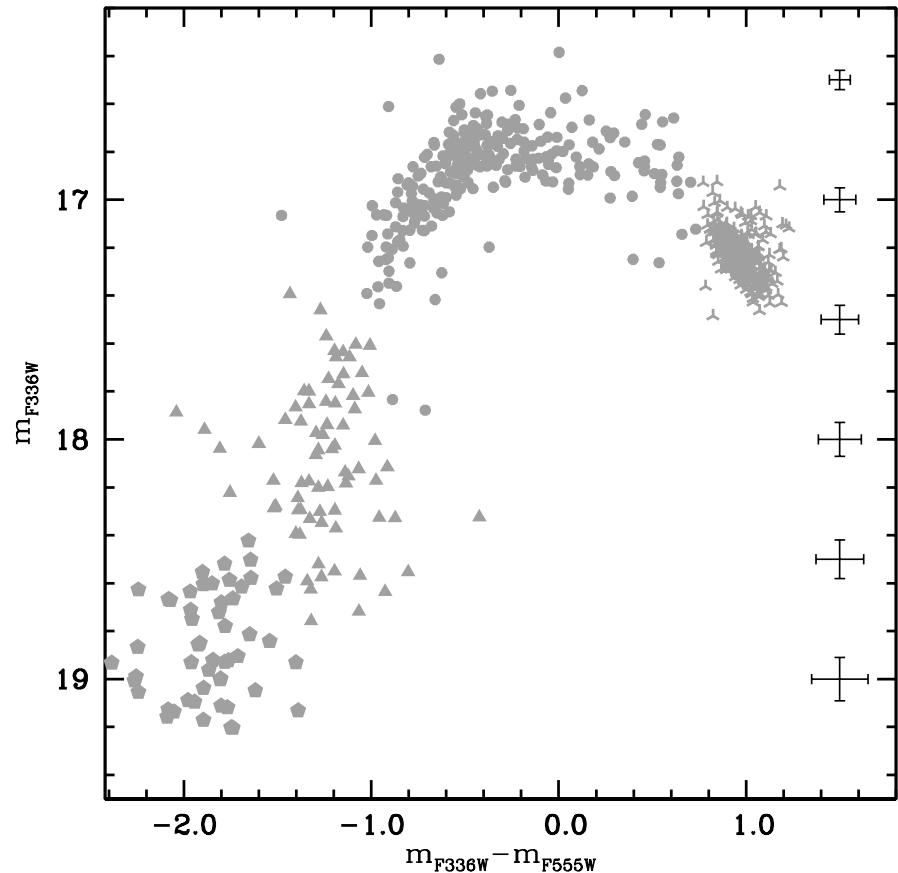


3 sub-populations with different He abundances have been observed from both photometric and spectroscopic analyses
(Piotto et al. 2007; Bragaglia et al. 2011; Pasquini et al. 2011)



The Horizontal Branch in UV: NGC 2808

Dalessandro et al. 2011



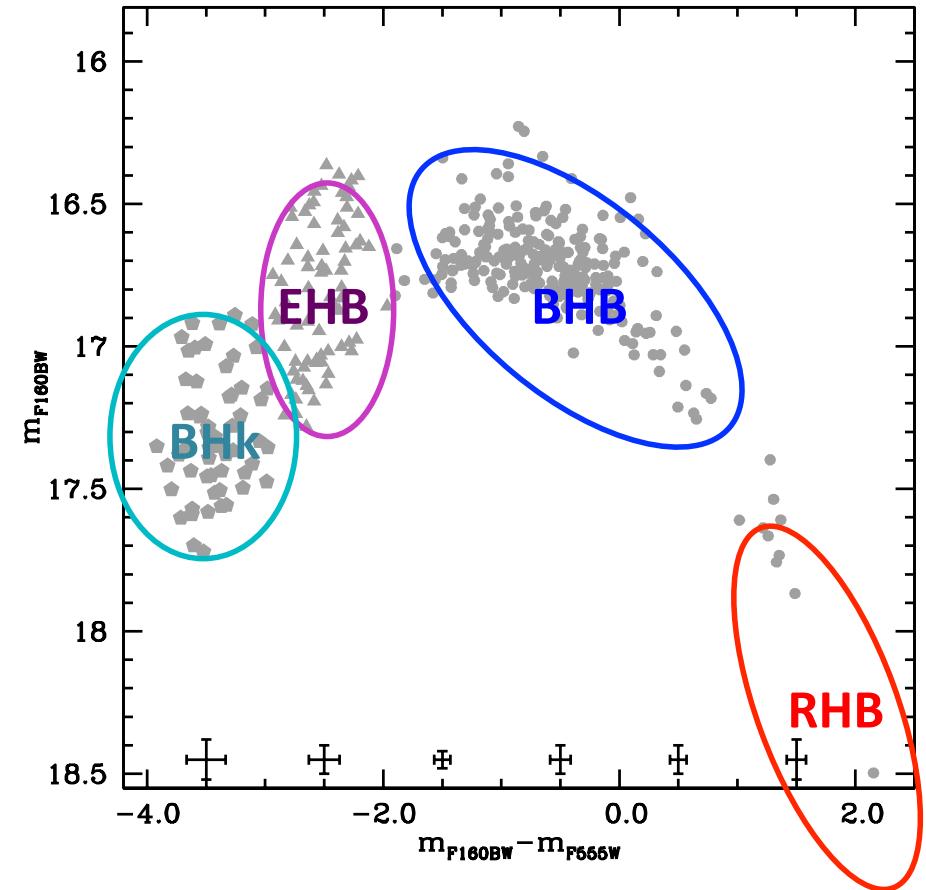
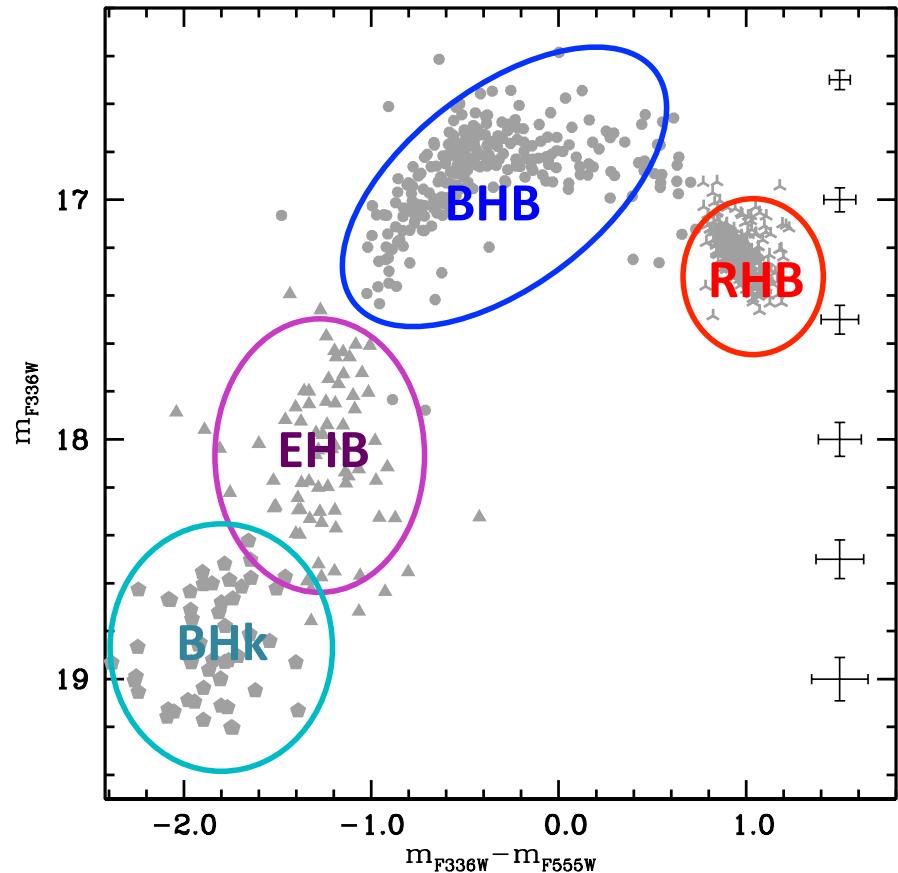
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The Horizontal Branch in UV: NGC 2808

Dalessandro et al. 2011



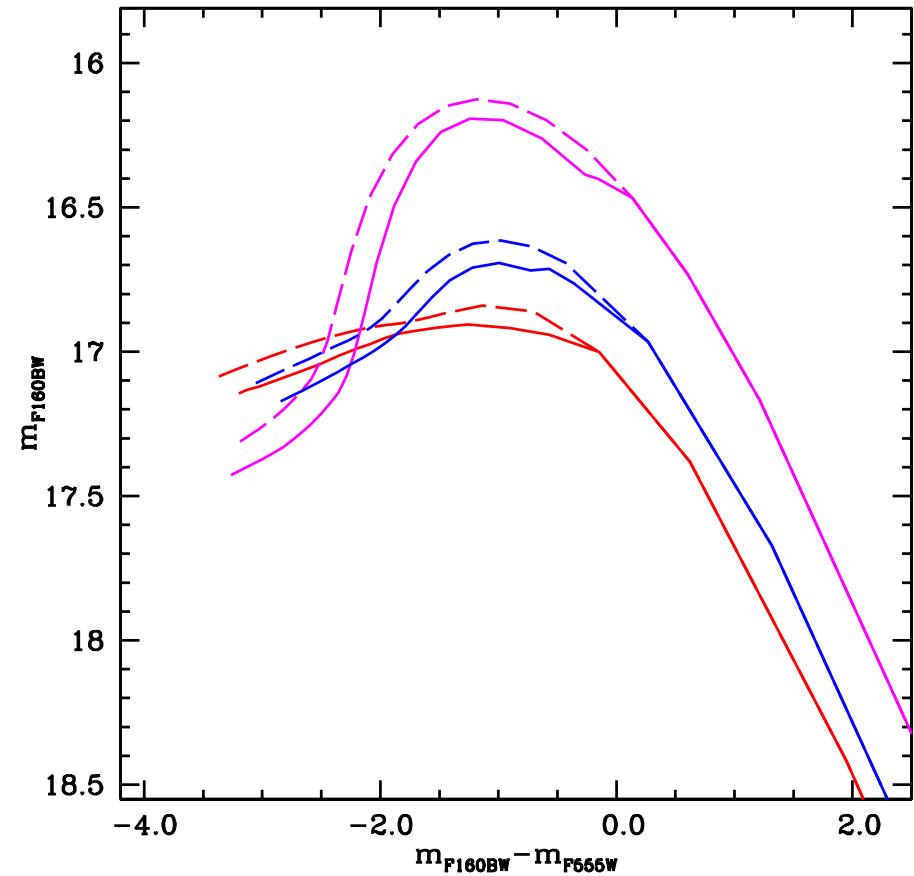
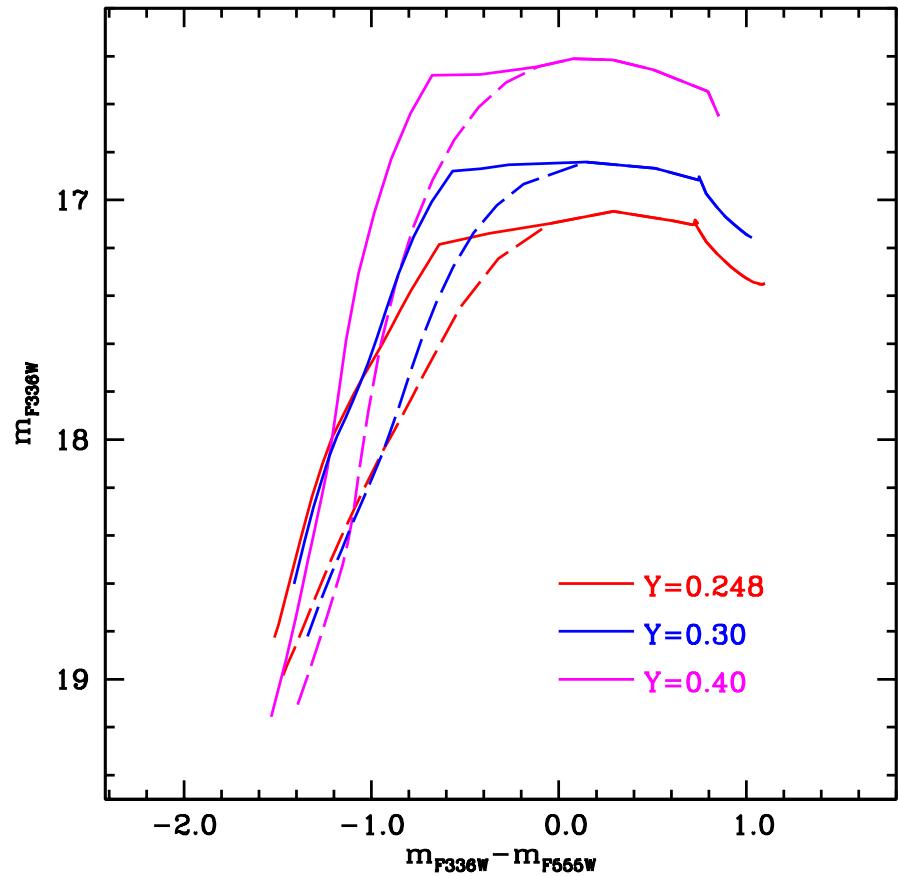
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The Horizontal Branch in UV: NGC 2808

Dalessandro et al. 2011



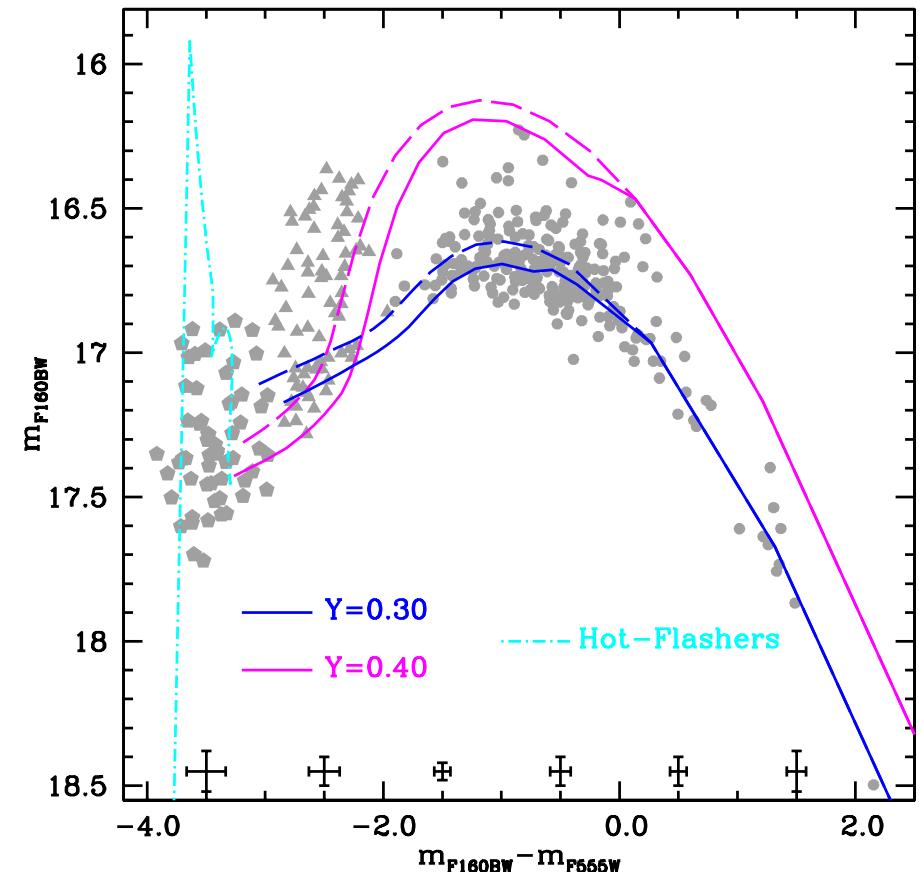
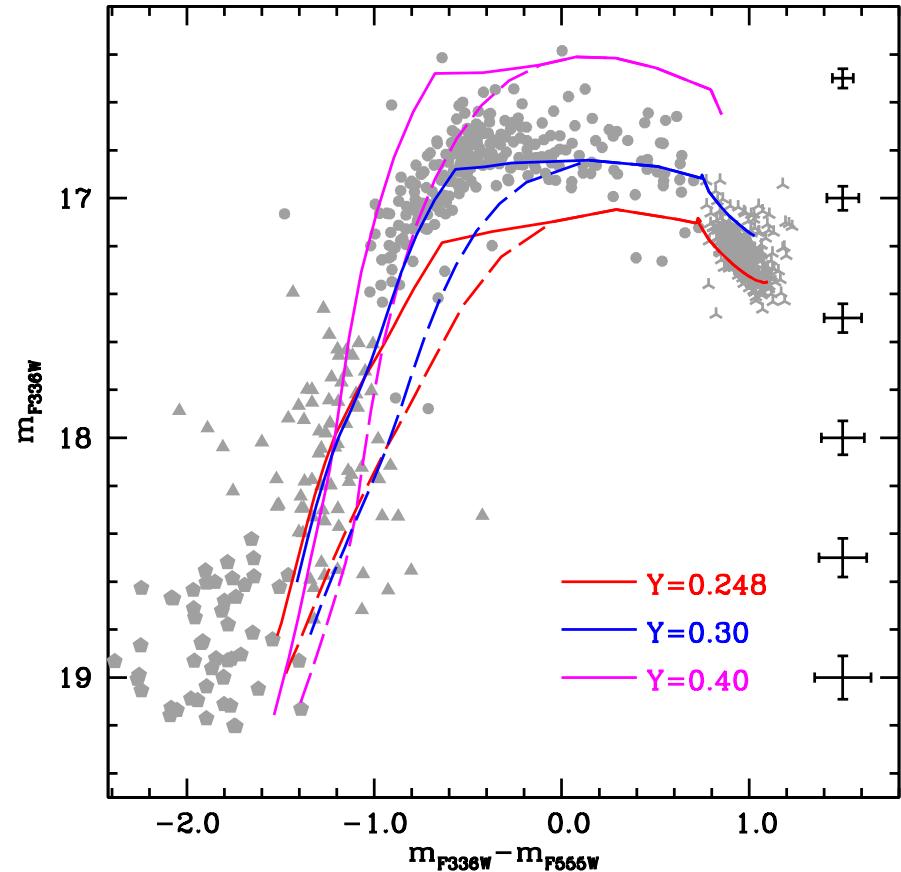
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The Horizontal Branch in UV: NGC 2808

Dalessandro et al. 2011

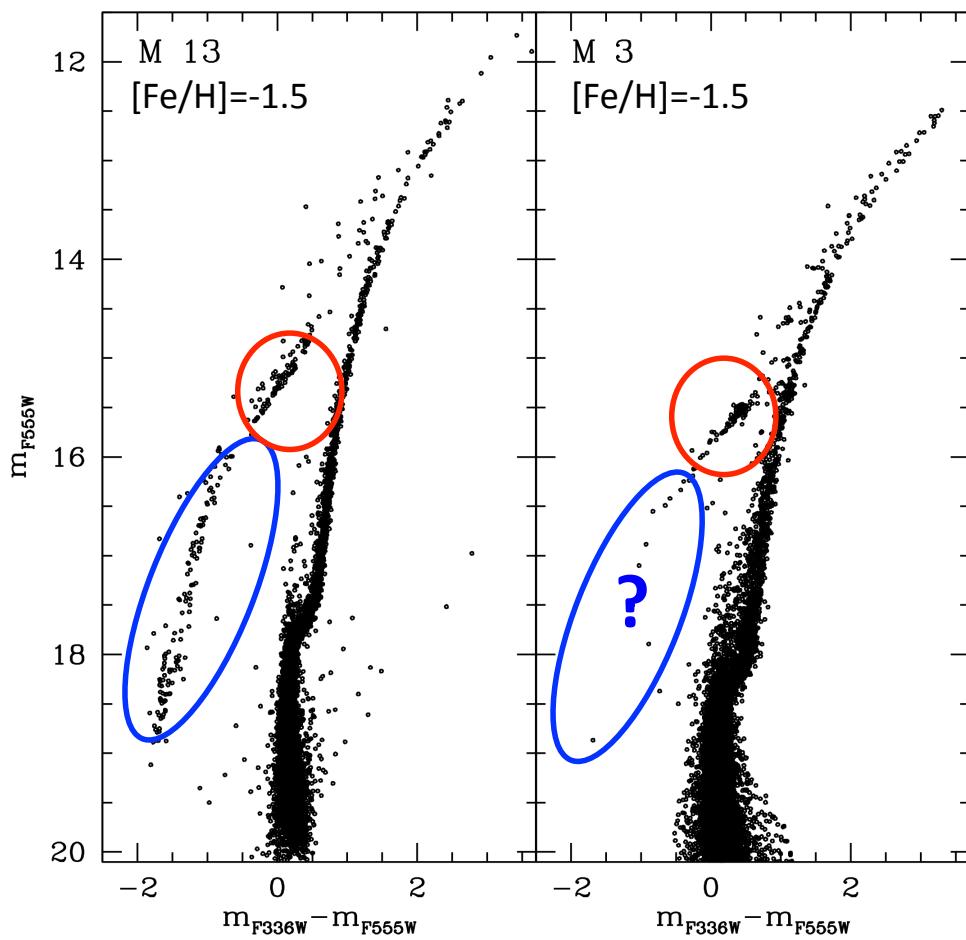


THE HB OF NGC2808 IS FULLY DESCRIBED BY USING 3
POPS WITH DIFFERENT He + HOT-FLASHERS

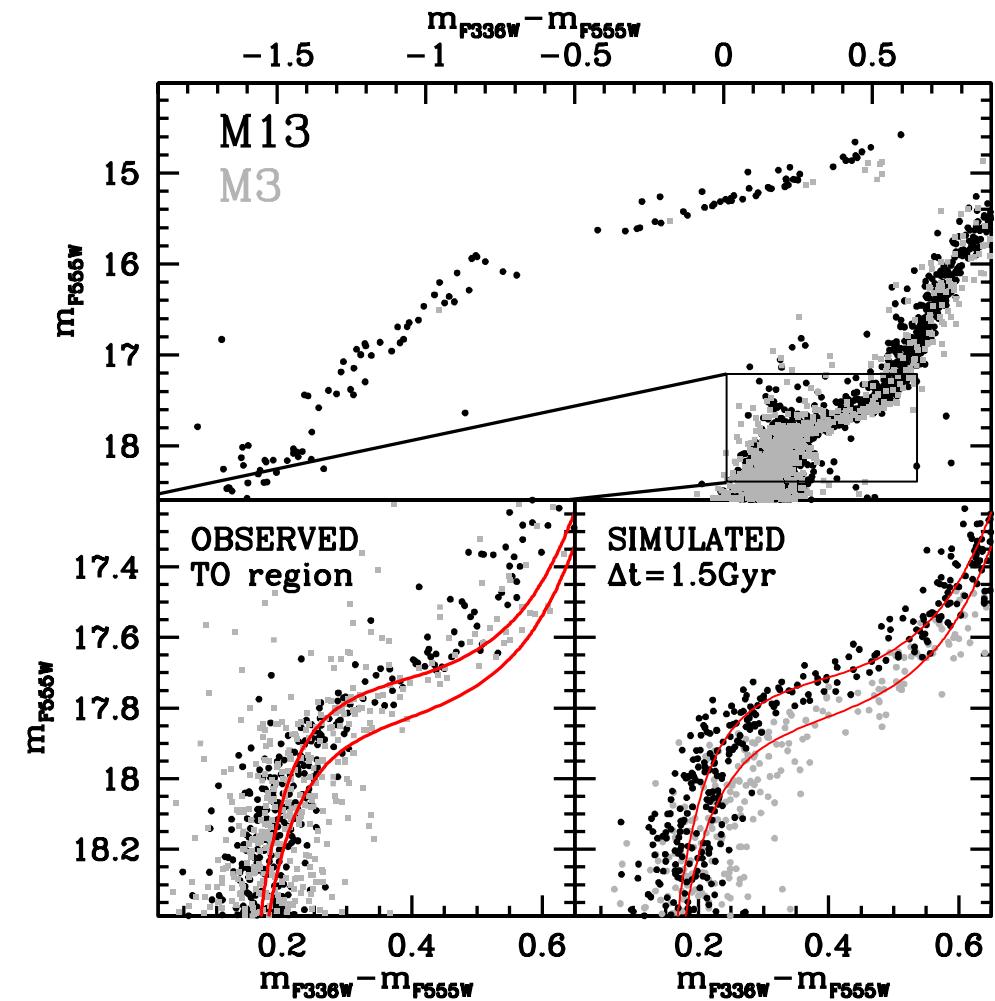
The Horizontal Branch in UV: M 3 – M 13

Dalessandro et al. 2013

DIFFERENT HB MORPHOLOGIES



SAME AGE



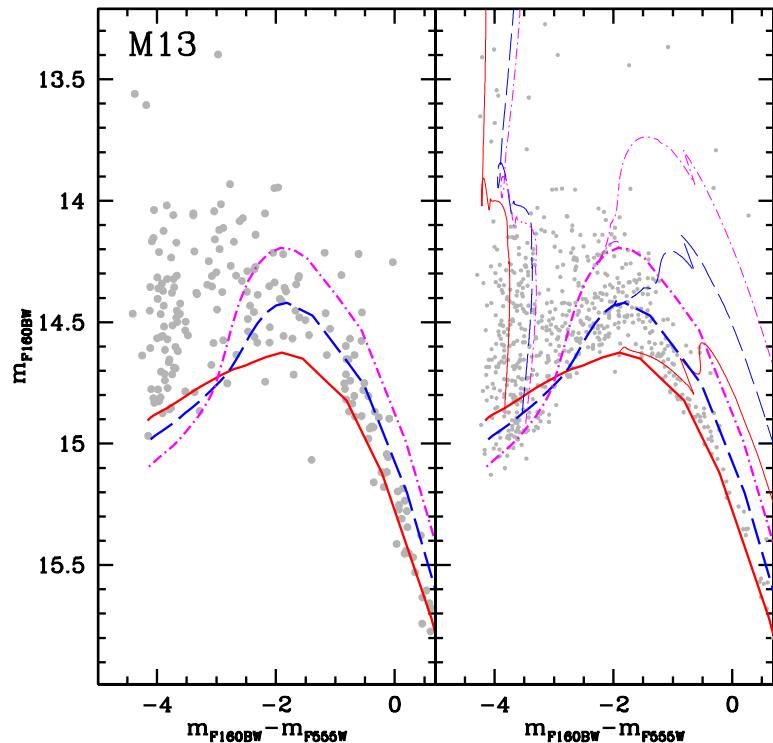
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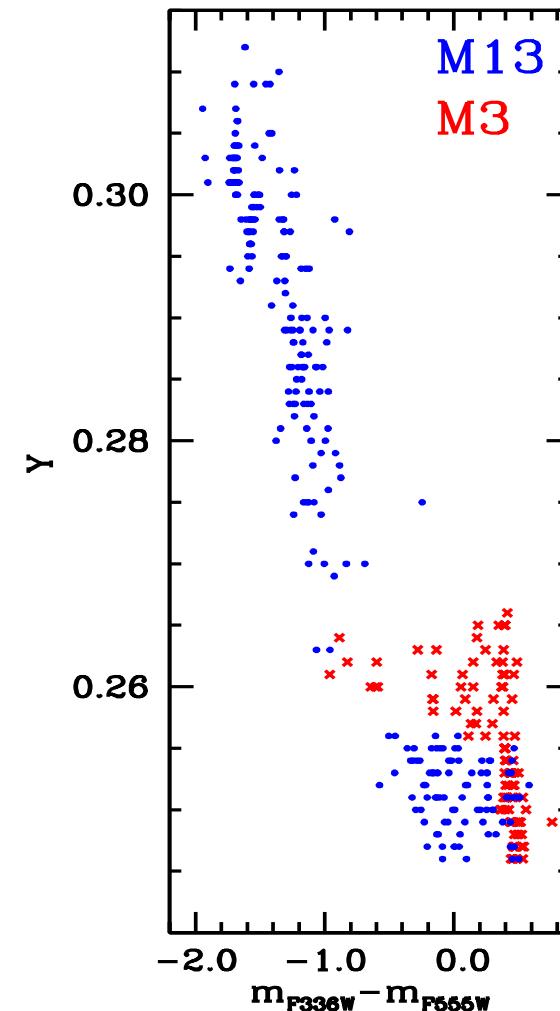
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The Horizontal Branch in UV: M3 – M13

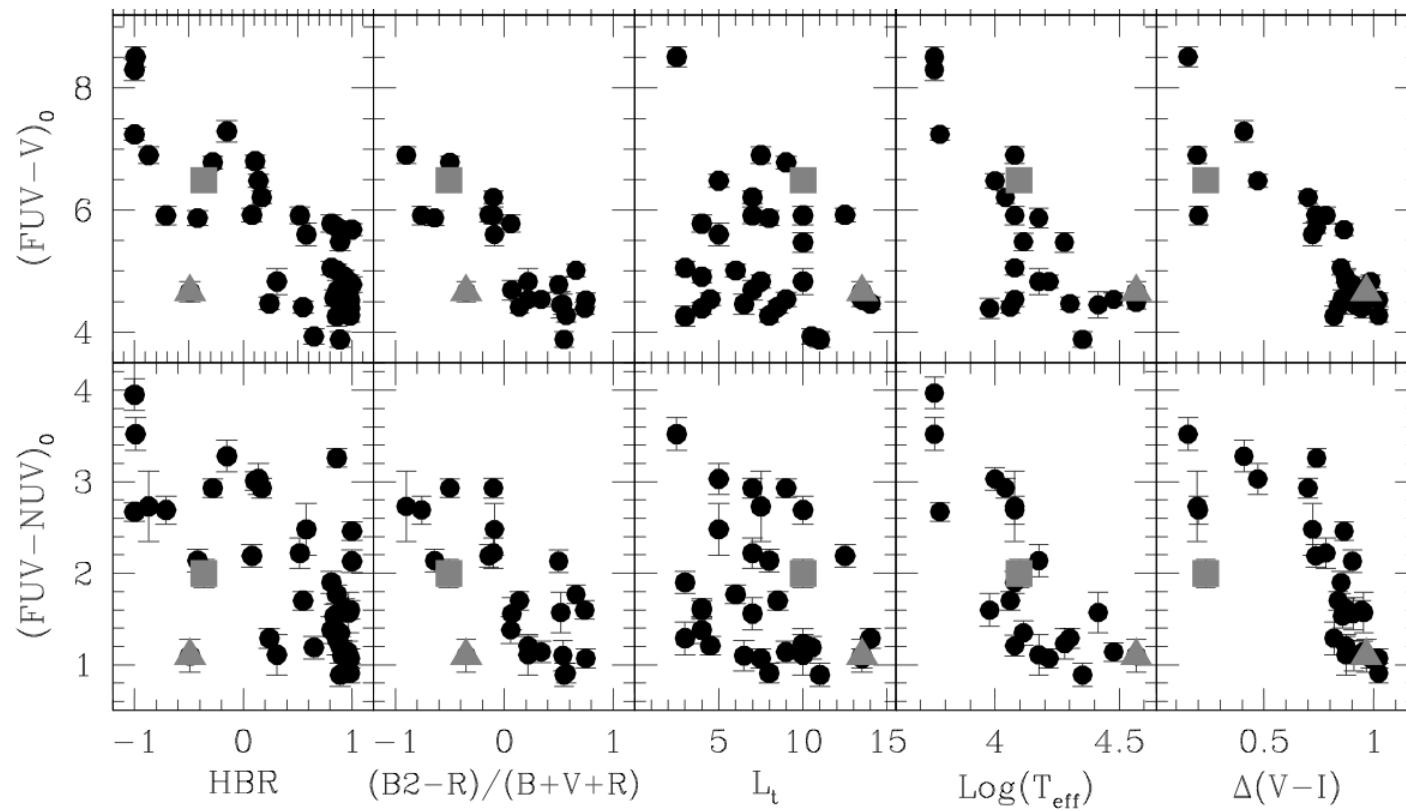


HBs are matched
only with different
He distributions

Dalessandro et al. 2013

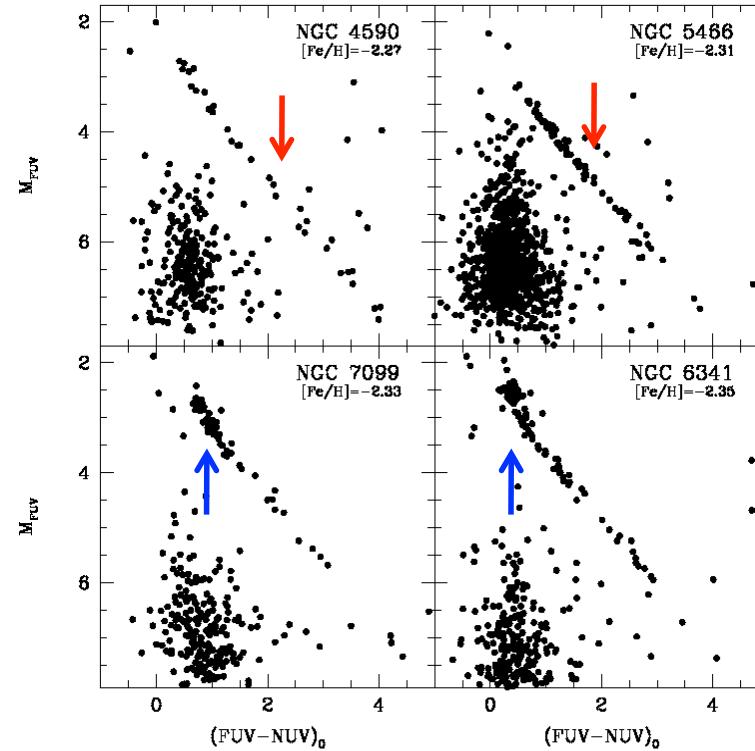
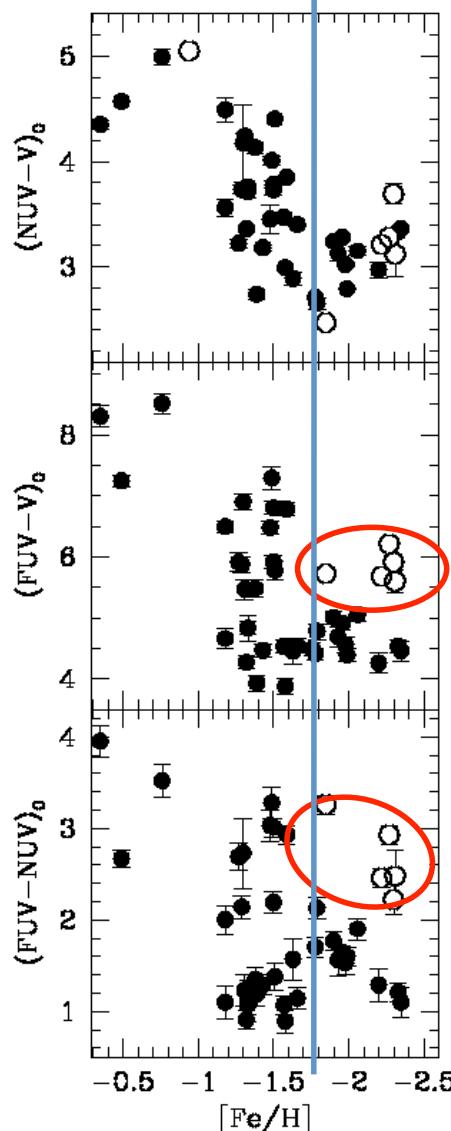


INTEGRATED PROPERTIES WITH GALEX



The Sagittarius clusters

Dalessandro et al. (2012)

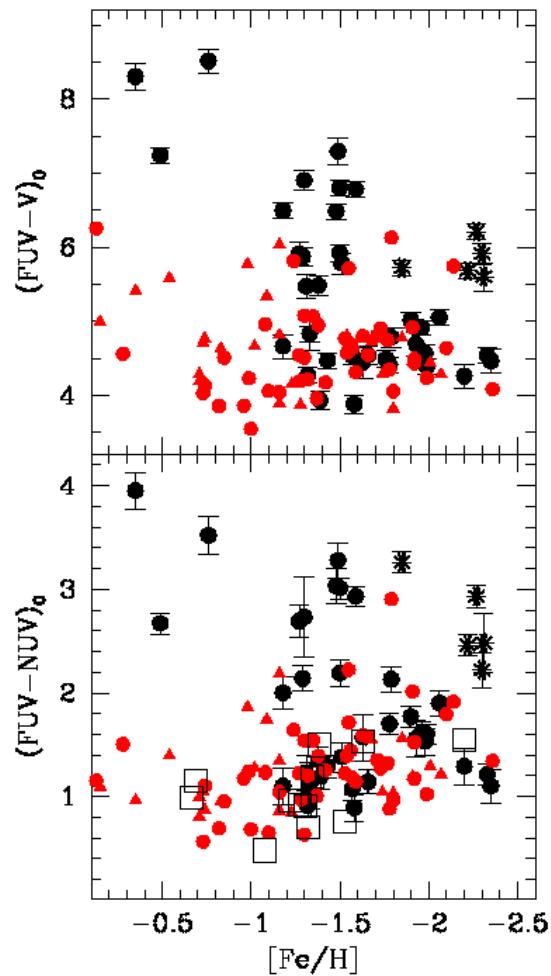


NGC4590, NGC5053, NGC5466, Arp2, Terzan8 and Palomar 12
are suggested to be connected with the Sagittarius Stream
(Dinescu et al 1999, Palma et al. 2002, Bellazzini et al. 2003, Lee & Majewski 2010)

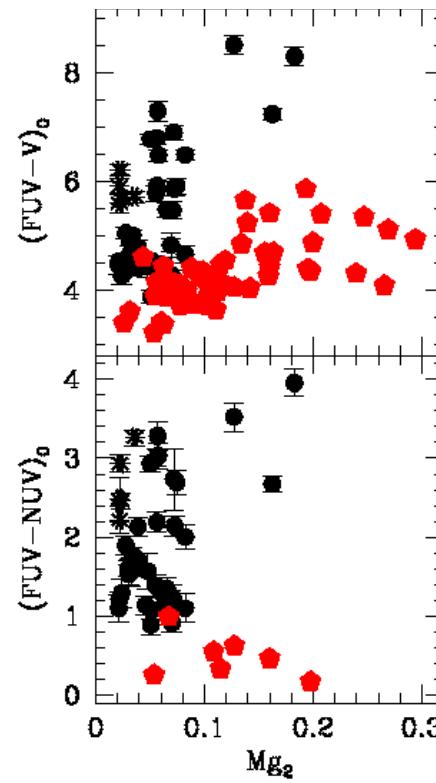
A comparison with the M31 and M87 GCs

Dalessandro et al. (2012)

On average M31 and MW
GCs have the same UV colors

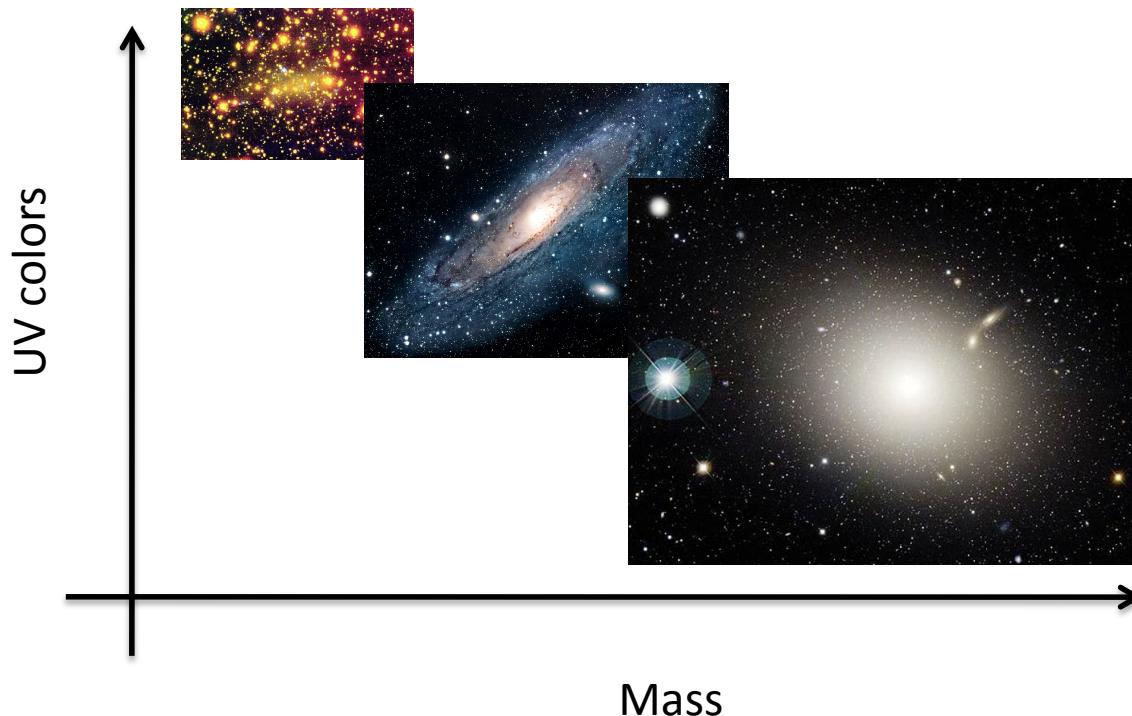


On average M87 GCs are
bluer than GGCs



Mass really matters

Dalessandro et al. (2012)



$M(\text{Sgr}) = 1.6 \times 10^8 M_{\text{sun}}$ (Law & Majewski 2010)

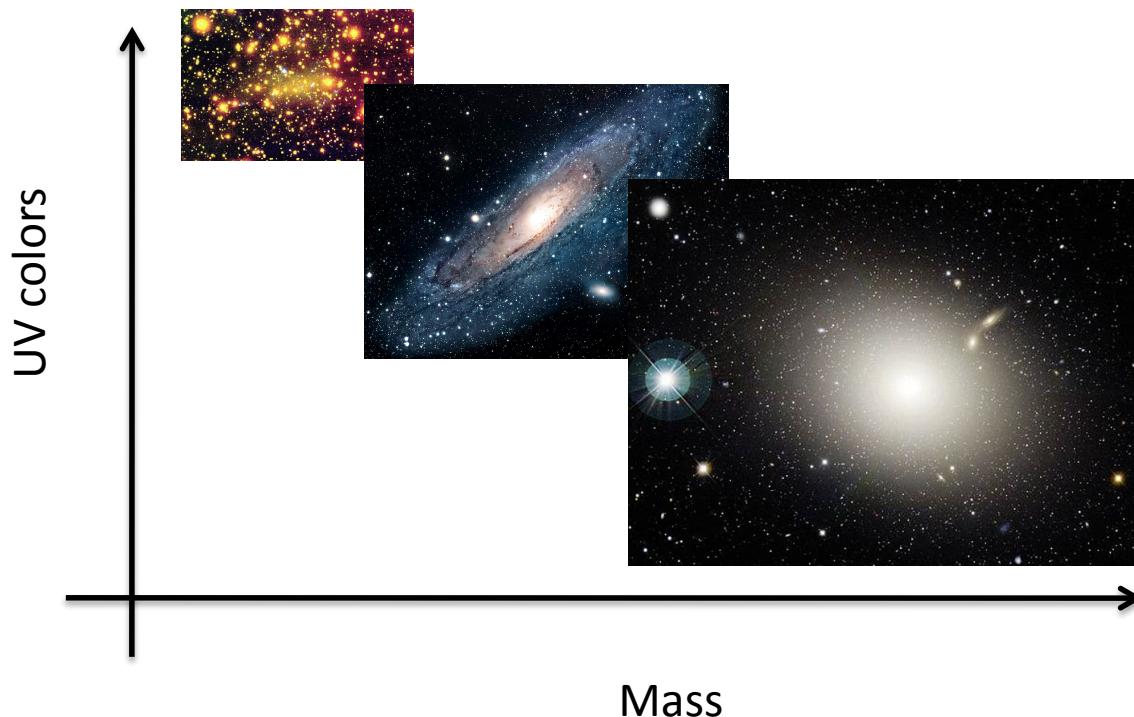
$M(\text{MW}) = 2.4 \times 10^{11} < M_{\text{sun}} < 1.2 \times 10^{12}$ (Little & Tremaine 1987)

$M(\text{M31}) = 3.7 \times 10^{11} < M_{\text{sun}} < 2.5 \times 10^{12}$ (Cote' et al. 2000)

$M(\text{M87}) = 1.7 \times 10^{13} < M_{\text{sun}} < 4 \times 10^{13}$ (Fabricant et al. 1980)

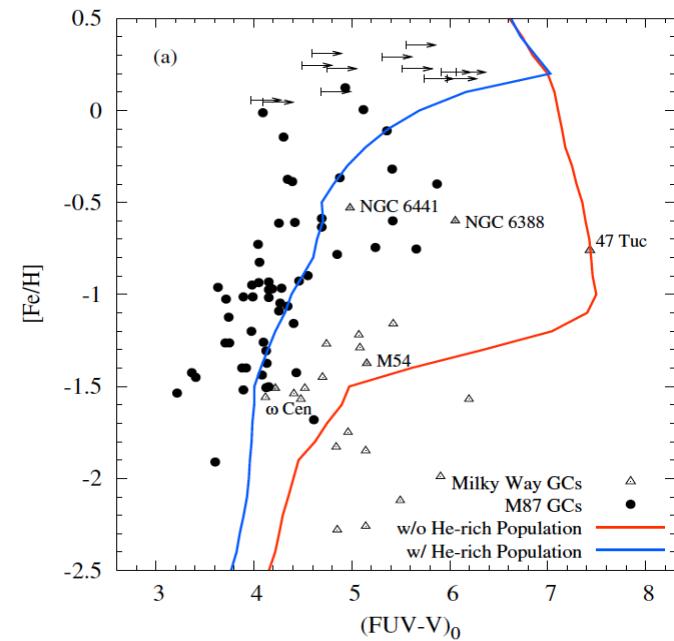
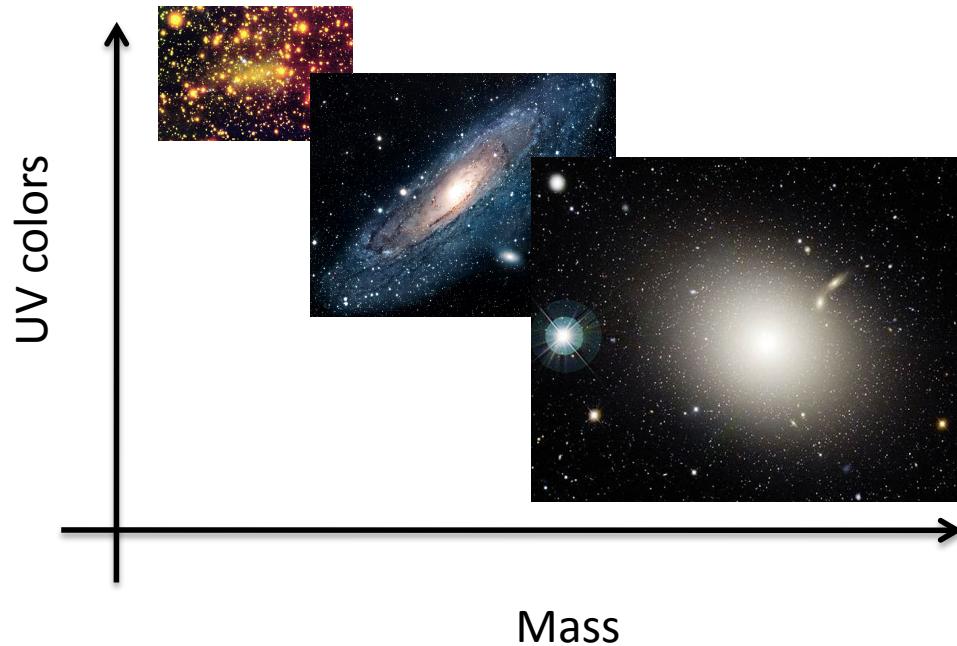
Mass really matters

Dalessandro et al. (2012)



UV colors of GC systems get bluer as the mass of the host galaxy gets bigger

Mass really matters



This might be linked to the survival rate of GCs in different environments

GCs in more massive galaxies are likely to undergo more complex history of star formation (Valcarce & Catelan 2011)



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Summary

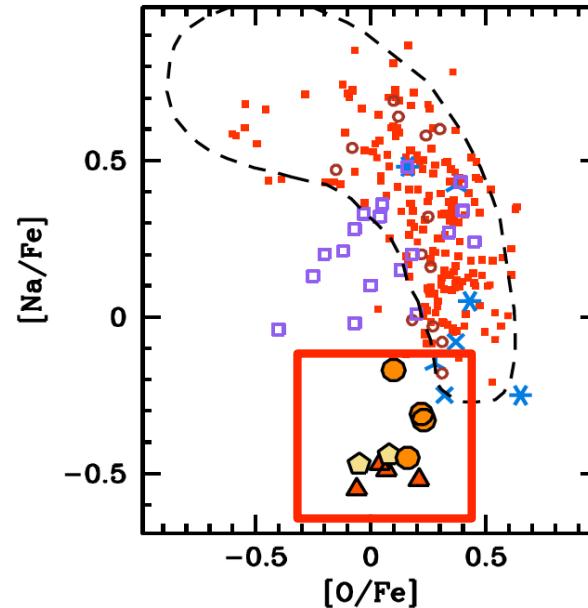
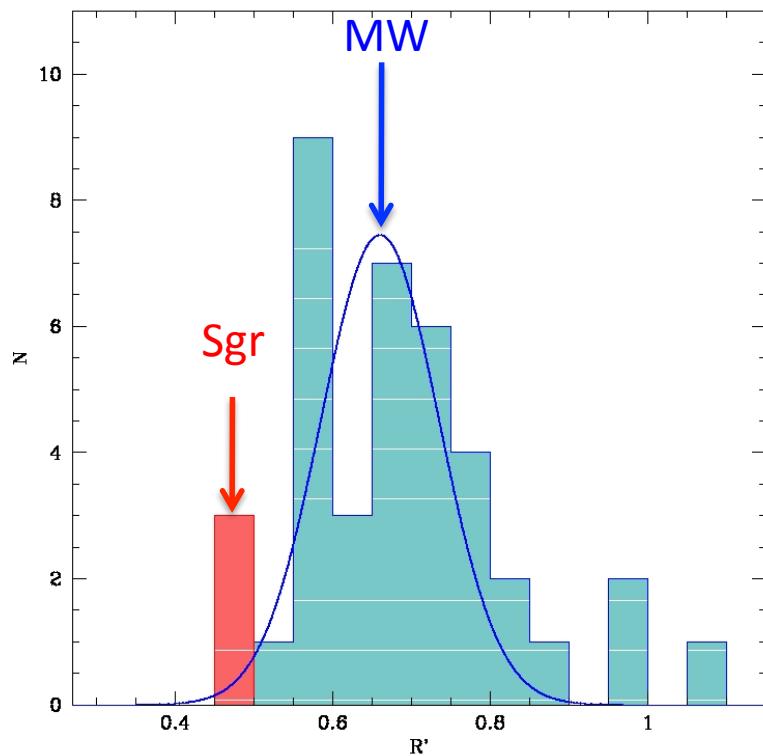
- We combined UV HST and GALEX data for a sample of GGCs with the aim to link resolved to integrated properties
- He content has a strong impact in shaping the HB of old stellar population (see the cases of NGC 2808 and M 3-M 13)
- We observe a general correlation between UV colors of GCs and mass of the host galaxies
- Differences might be linked to the survival rate of GCs in different environments

Thank you!

Visit our web-site: www.cosmic-lab.eu

The screenshot shows the homepage of the Cosmic-Lab website. The background is a dark, star-filled image of a galaxy or star cluster. At the top center is a white rectangular header containing the "Cosmic-Lab" logo, which features a blue cross-hatched pattern forming a stylized 'C' shape. Below the logo, the text "ALMA MATER STUDIORUM" and "UNIVERSITÀ DI BOLOGNA" is followed by "DIPARTIMENTO DI ASTRONOMIA". To the right of the header is the European Research Council (ERC) logo. On the left side of the main content area, there is a vertical sidebar with links: "Home", "The team", "Papers", "Telescope time", "Press Releases", "Products", and "Presentations". The main content area has a dark blue background. It features the text "WELCOME TO" in large white letters, followed by the "Cosmic-Lab" logo and the text "Star Clusters as Cosmic Laboratories for Astrophysics, Dynamics and Fundamental Physics" in white.

The Sagittarius clusters



$$\langle R'(\text{Sgr}) \rangle = 0.48 \pm 0.01 \quad \langle R'(\text{MW}) \rangle = 0.74 \pm 0.18$$

A t-test between these mean values gives a P~99.9% that they are different

See also Perina et al. 2012; Fusi Pecci et al. 1993