## New Frontiers of Globular Cluster Studies with Precision Stellar Population Synthesis Models

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"Stars. Or rather, the drains of heaven--waiting. Little holes. Little centuries opening just long enough for us to slip through."-- Ocean Vuong

### Villaume et al. 2017a and Conroy, Villaume, et al. 2018 for details on low-metallicity extension to the absorption line fitter



## Currently working on the next update to alf



SPACE TELESCOPE





#### Last big facility was *HST* which gave us the paradigm <u>pervasive</u> bimodality



## Broadband colors of GCs can be easily converted into metallicities through a color—metallicity relation



# Broadband colors of GCs can be easily converted into metallicities through a color—metallicity relation...or not...?



### **Dichotomy of Observations of GCs**

Star cluster people with a lot of detailed information on a few dozen objects all within the Local Group

OR

Extragalactic galaxy evolution people with coarse information on many thousands of objects



Two assumptions have underpinned the use of GCs to trace galaxy formation and assembly beyond the Local Group:

1.) GCs are simple stellar populations



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#### Is the CMR linear or does it have a broken power-law shape?



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#### Spectroscopic constraints indicate that neither CMRs are "wrong", there is genuine scatter for blue GCs!



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#### So then what causes the scatter in metal-poor GCs?



#### Mass of the host galaxy?













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# Precision SPS models are bridging this gap

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**M87 GC Metallicity Distribution** 



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Median S/N of Strader+2011 Sample

Individual objects that look similar can have different internal properties that will affect *population* studies of those objects



#### What do we know that people in the 90's didn't?



#### We know that there are many kinds of objects that fill the gap between canonical star clusters and galaxies





log radius

# How to distinguish objects that appear to be similar but have had different formation pathways?







### Stellar population parameters are powerful probes of formation history













The expanded sample in Cheng, **Villaume** et al. (in prep.) confirms the original findings



### The two UCDs in our sample that have **confirmed SMBH measurements** have bottom-heavy IMFs



Detailed stellar population parameters are a way to disentangle the formation pathways of liminal objects



## takeaways

"What is a GC?" is not just a question for pendants. It affects our understanding of GC formation and how we use GC systems to understand galaxies.

#### We need to be more careful the greater in distance we go

## We need to model *representative* samples of individual GCs with precision SPS models

GC color variation at fixed metallicity is not only a challenge for observational constraints on galaxy assembly but also theories on massive star cluster formation. Why would massive clusters care about their global environment?

#### Detailed Stellar population parameters of many, many more individual GCs is needed

Formation models that form and evolve GCs in tandem with their environment are going to be crucial