Modeling the Color Difference of Two Sub-Populations in Intermediate-Age Globular Clusters (GCs)

Towards the Understanding of the Nature of Sub-Populations in GCs

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Pomona College
STScI SASP

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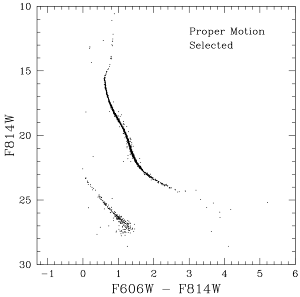
Outline

1. Motivation
   - General Background on Stellar Population in GC
   - Photometric and Spectroscopic Evidence for the Existence of Two Sub-Populations in GCs
2. Hypothesis and Prediction
3. Modeling Approach
   - Step 1: Computing the Stellar Atmosphere with ATLAS12
   - Step 2: Synthesizing the Stellar Spectra with SPECTRUM
   - Step 3: Convolving the Stellar Spectra with SYNPHOT
   - Effectiveness Test against Observational Data
4. Result

"Simple" Globular Clusters?

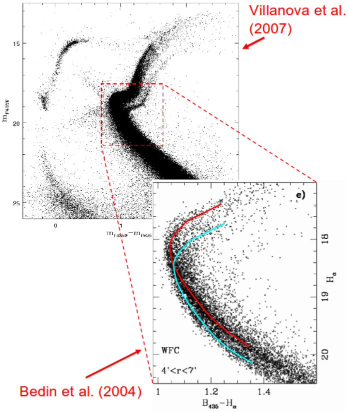
Globular Clusters were thought to be the best examples of Simple Stellar Population (SSP):

- Born at the same time
- In the same volumn of space
- From a gas cloud of homogeneous chemical composition



HST/ACS CMD of NGC 6397 (Richer et al. 2008)

Well-Known Exceptional Case: Omega Centauri



- Large spread in [Fe/H] among RGB stars
- Main Sequence also split into two (Bedin et al. 2004)

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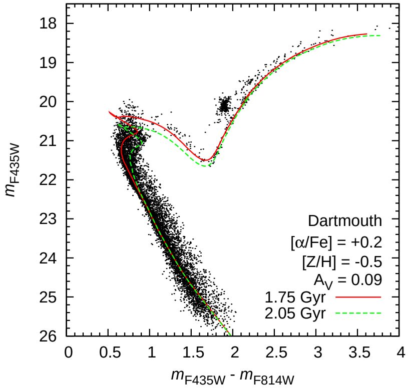

- Wide main-sequence turnoff point (MSTO)
  ==> Multiple Sub-Populations
- Narrow RGB
  ==> No metallicity difference among sub-populations
- Isochrone fitting result
  ==> Age ranges from ∼1.5 Gyr to ∼2.0 Gyr with [Fe/H]=-0.5

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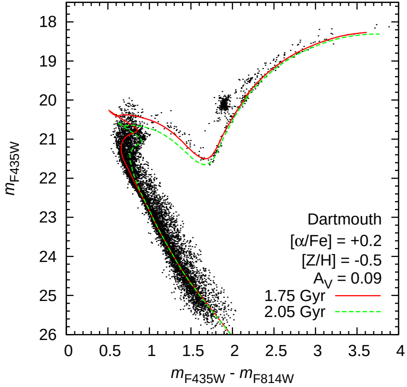

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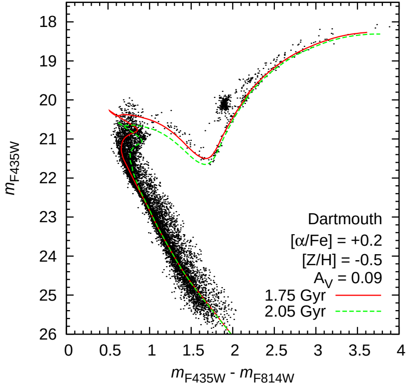

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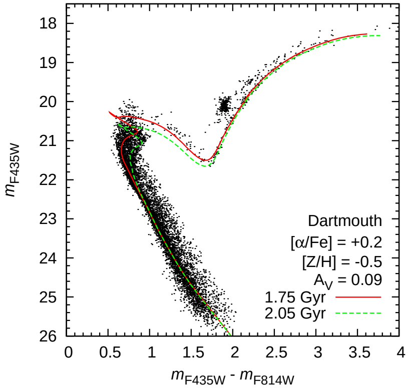

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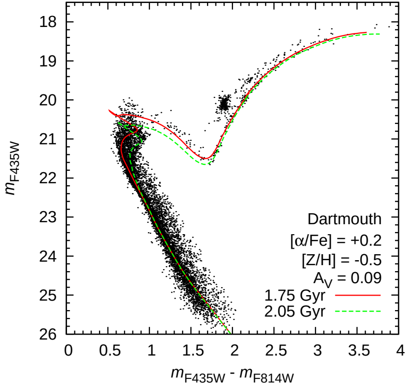

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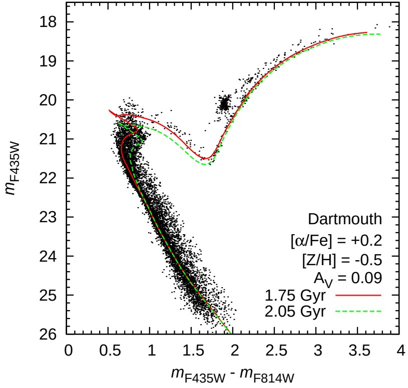

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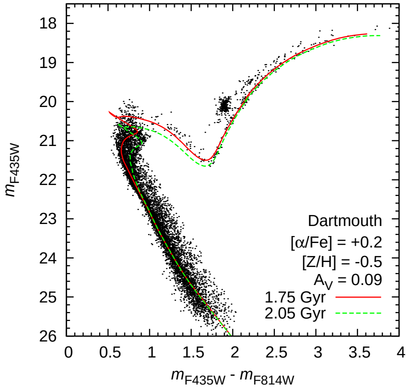

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Possible Explanation

How to account for the homogeneity of metallicity and difference in age?

Suggested Cluster Formation Scenario:

- Second-generation stars were formed by material lost by slow winds of rotating massive stars
- Such stars undergo CNO-Cycle nucleosynthesis
- Consequence:

Two generations differ in lighter element abundance

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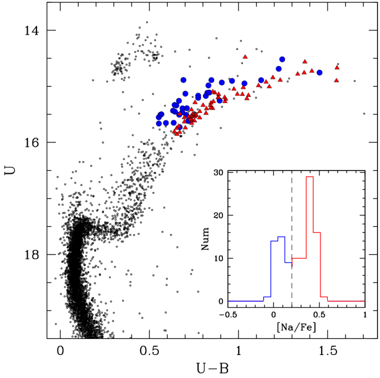
High Resolution Spectroscopy on 105 RGB stars in Old (∼12 Gyr) Galactic NGC 6121



- Chemical abudance analysis reveals two catagories of stars in terms of CN-band strength

[el/Fe]	CN-S	CN-W
[C/Fe]	-0.66	-0.66
[N/Fe]	+1.08	+0.42
[O/Fe]	+0.33	+0.45
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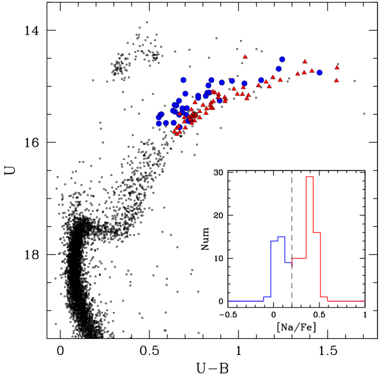

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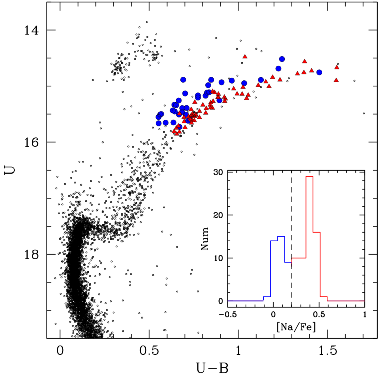

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Hypothesis and Prediction

Hyphothesis:
Younger Sub-Population born from dusts of Older Sub-Population

Prediction:
Lighter Element Abundance Difference(Unresolved in intermediate-age GCs)

How to test the prediction:

- Photometrically rather than spectroscopically
- ACS: limited wavelength coverage does not reach the CN-band
- WFC3: covers almost all useful wavelength

Careful selection of filters should be able to resolve the color difference between the two sub-populations!

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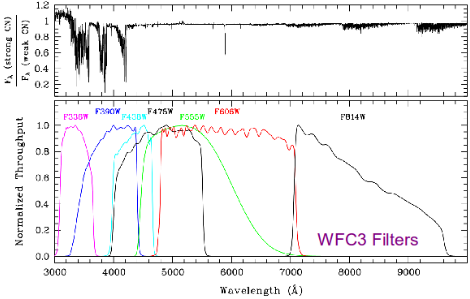

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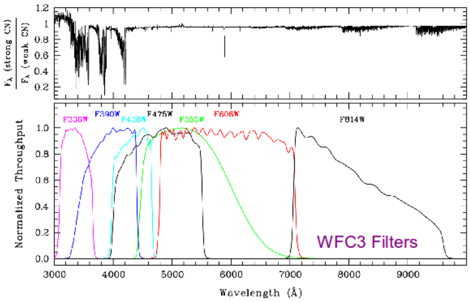

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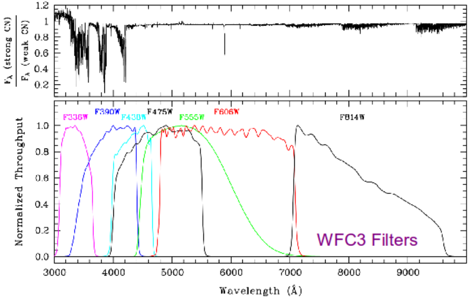

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Computing the Stellar Atmosphere with ATLAS12

ATLAS12:FORTRAN code to compute model atmospheres

- Plane Parallel Layers
- Hydrostatic Equilibrium
- Chemical Abundances Determines Line Opacity

Key Parameters:

- Metallicity [Fe/H]
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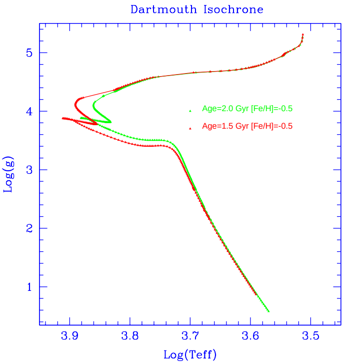

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Step 2: Synthesising the Stellar Spectra with SPECTRUM

SPECTRUM

- Reads in
  - Stellar Atmosphere file, inherits Teff, Log(g), [Fe/H]
  - Chemical Abundance File
- Computes emission and absorption lines
- Integrates flux over given the wavelength range

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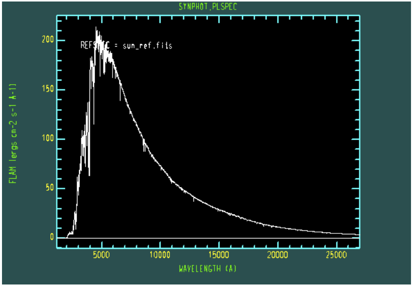

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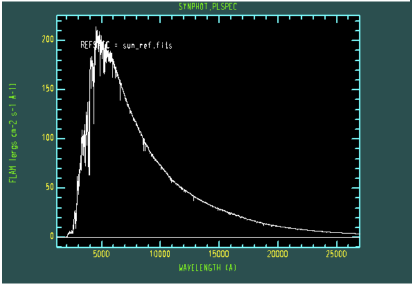

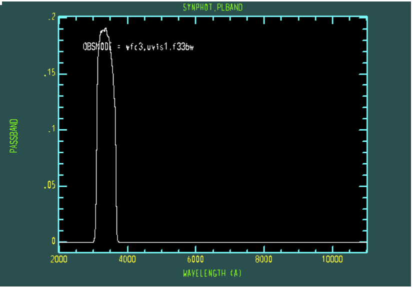

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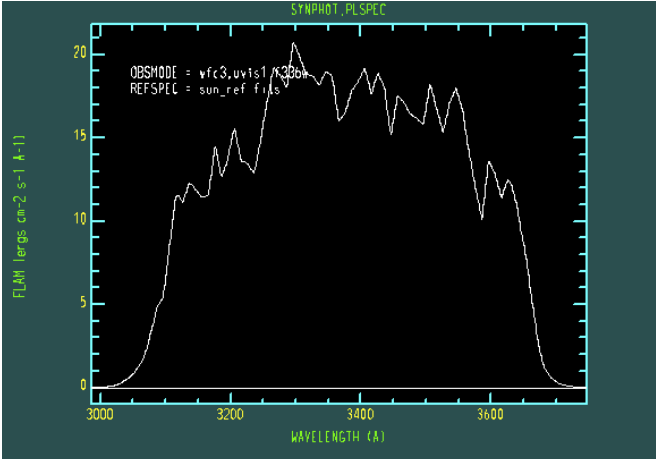

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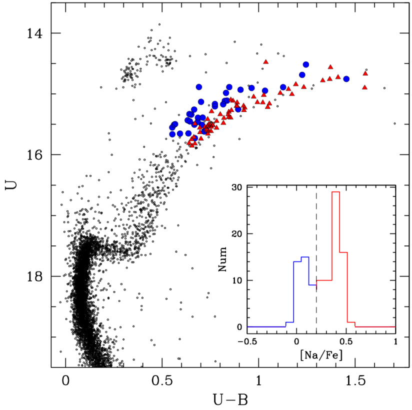

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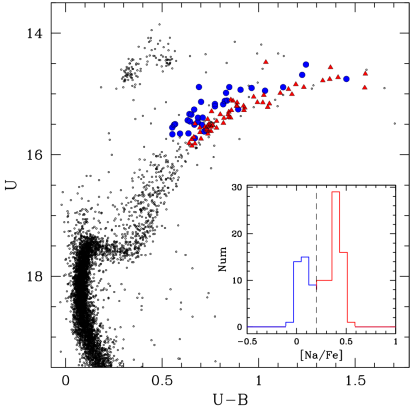

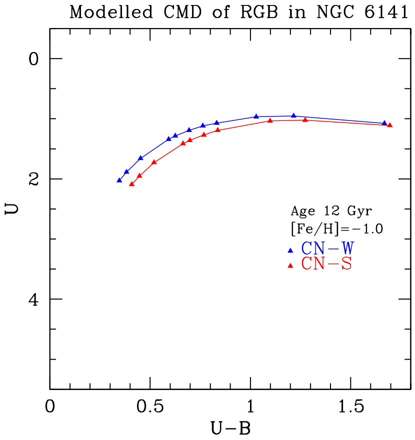

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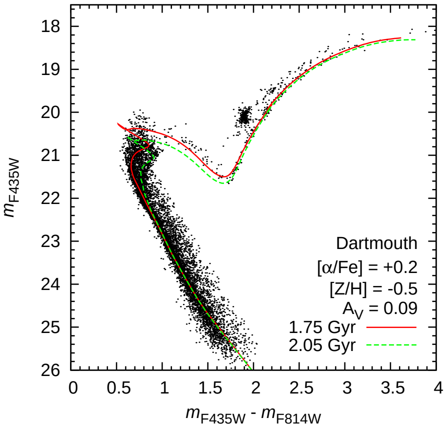

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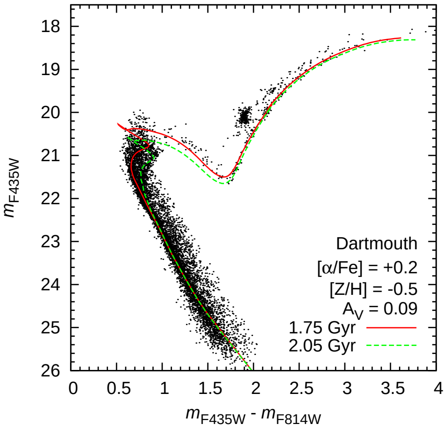
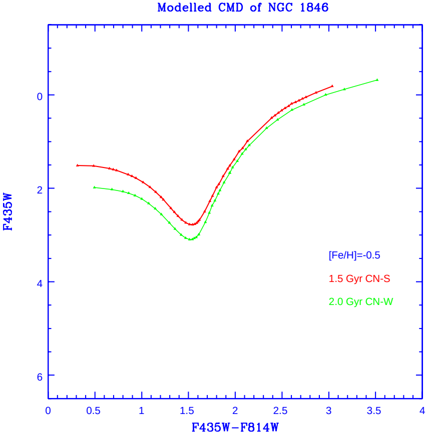
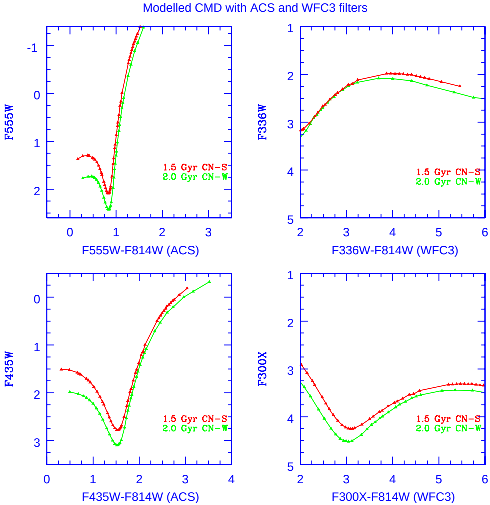




Significant Color Split on RGB with WFC3 Filters



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Castelli, F.: Co-Author of ATLAS12

Gray, O.: Author of SPECTRUM