Distinguishing Multiple Populations in Galactic Clusters: Process Validation

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Introduction

Globular clusters are groups of stars tightly bound together by their own gravity. These clusters were originally believed to contain a single population of stars, meaning all the stars were the same age and had the same chemical composition. More recently, though, it was discovered that some globular clusters had multiple populations. It is thought that in these clusters one generation of stars was born out of pure interstellar gas. These stars created new elements through nuclear fusion, and released them into space. This enriched gas fell towards the center of the cluster and formed a new population of stars. One way these populations can be seen is through a color-magnitude diagram, in which a star's brightness is plotted against its color. Plotting all the stars in a single population this way produces several distinct shapes, one of which is known as the red giant branch. Plotting two populations, then, produces two red giant branches. However, when using ground-based telescope data, these two red giant branches can become blended due to photometric uncertainty and contamination by stars that aren't truly part of the cluster. Our research this summer focused on reducing uncertainty and contamination in order to see those two red giant branches.

Objectives

- Determine accurate magnitudes (brightnesses) for stars in the globular clusters M13, M56, and NGC 6712, as well as in the open cluster NGC 6791
- Reduce uncertainty and contamination from non-cluster stars to make clean color-magnitude diagrams
- Analyze these color-magnitude diagrams for evidence of multiple populations in the clusters

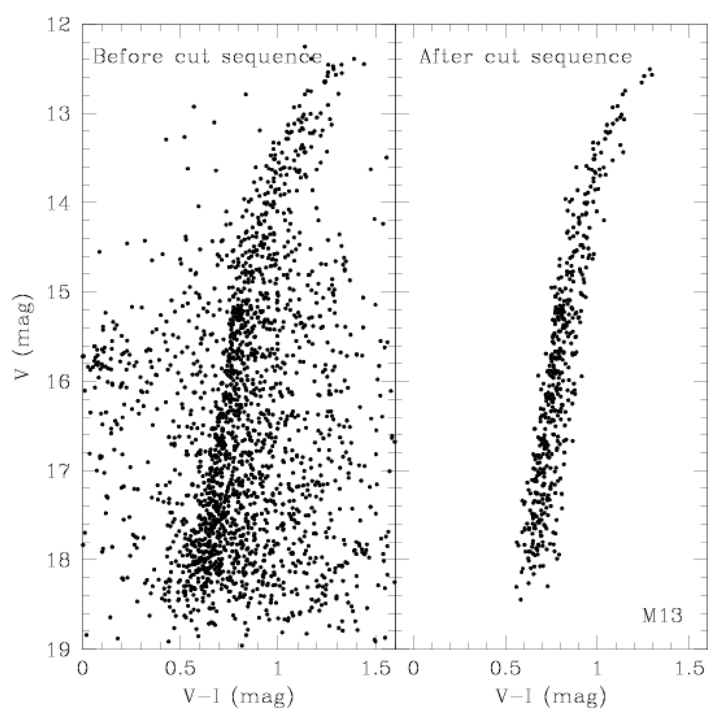
Methods

DAOPHOT

To measure the brightnesses of cluster stars, we used the software package DAOPHOT. DAOPHOT works by identifying stars using the shape of their light profiles and iteratively subtracting them from an image. This process allows us to measure stars that are obscured by other stars. This resulted in photometry for several thousand stars in each of four Johnson-Cousins filters: B, V, R, and I.

Isolating the Red Giant Branch

After obtaining the magnitudes from DAOPHOT, we made color-magnitude diagrams. This produced a red giant branch, but the diagram also had a lot of scatter. To reduce this scatter, we implemented several cuts to eliminate poorly measured stars and stars that we were confident were not part of the cluster. This left us with a much cleaner red giant branch.



Color-magnitude diagram of M13 before and after cut sequence.

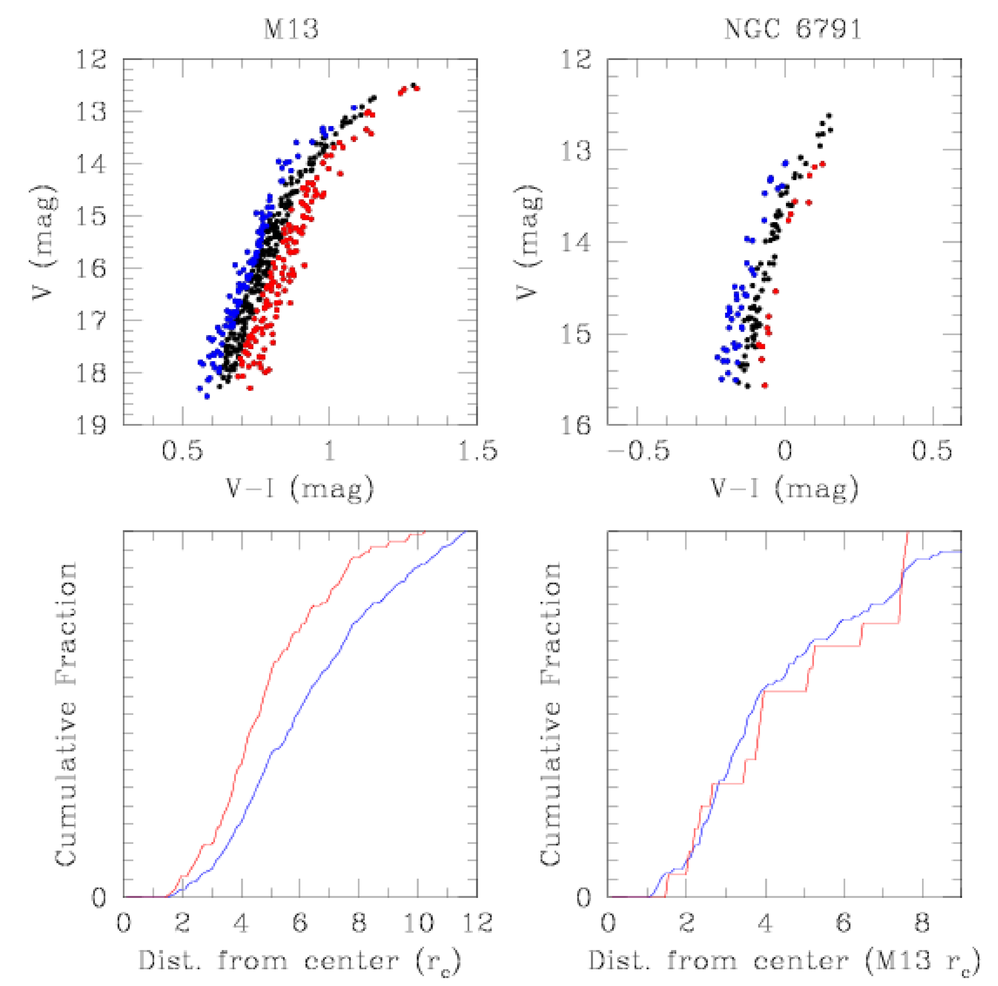
Analysis

Our last step was to isolate the stars that we were confident were either red stars or blue stars. This is because the chemical composition, the distinguishing feature of the two populations we were looking for, manifests itself in the color of the stars. At this point, we had isolated the stars we believed comprised the two populations, but we needed to show that they were in fact two distinct populations. To do this, we looked at their positions within the cluster.

Results

To show that the two groups of stars we had found were part of two different populations, we made a cumulative radial distribution plot. This plot shows the percentage of stars that are within a certain radius of the center of the cluster. By plotting the distribution of red stars compared to blue stars, we will be able to see where those stars are located. A significant difference in the distributions of those stars would suggest the existence of two distinct populations.

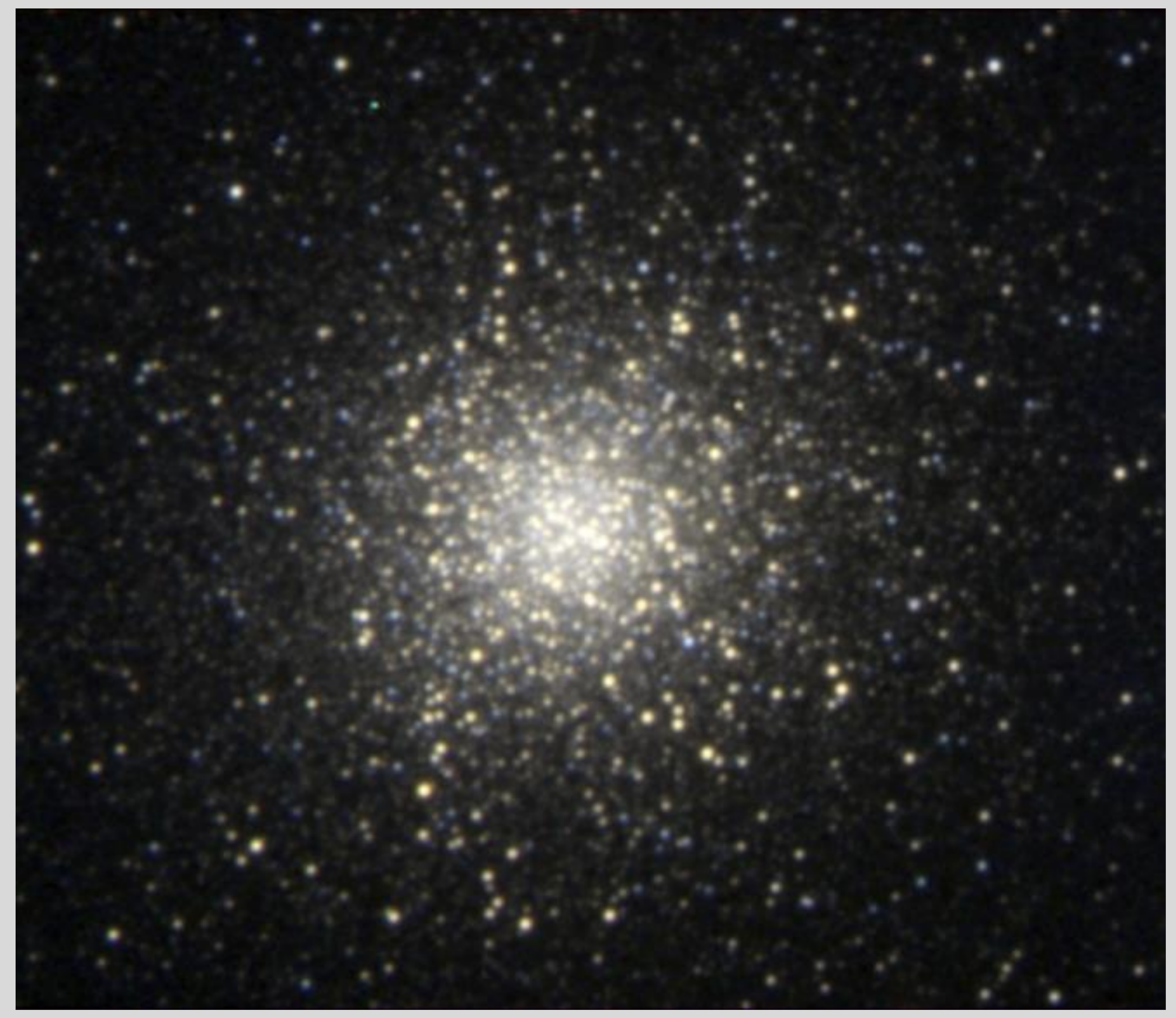
By using this method, we were able to see two populations in M13, and we were unable to see two populations in NGC 6791. These were both anticipated from previous studies. Analyzing these clusters was used as a check to make sure our process was working correctly.



Top: Color-magnitude diagrams of M13 and NGC 6791 with selected red and blue stars highlighted.

Bottom: Cumulative radial distribution plots showing the distributions of red and blue stars within these clusters. In M13, the red star subgroup is more centrally concentrated.

Next we will turn our attention to M56 and NGC 6712, both globular clusters located within the galactic disk. This will pose a further challenge, as both clusters will experience more contamination from non-cluster stars than M13 did. We will be improving upon our previous work done on M56 using increased signal-to-noise.



Color image of M13, made using data from the Calvin-Rehoboth Observatory

Conclusions

This summer, we spent much of our time creating a process that would allow us to look for multiple stellar populations in globular clusters. We had reasonable success, finding that there was a 96% and 3% chance of there being at least two populations in M13 and NGC 6791, respectively. These results are consistent with published results, which gives us confidence in our process.

Next Steps

1. Assess the impact of cut choices on results.
2. Incorporate GAIA proper motions where possible, to further reduce contamination, and assess the degree of improvement.
3. Complete previous analysis of globular cluster M56.
4. Apply validated procedure to unstudied globular cluster NGC 6712.