A Study of Open Cluster M48

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Aperture photometry and profile-fitting techniques were used on *ubvy*, *Hβ*, and *Ca* frames of open cluster M48. After instrumental magnitudes were found, *beta* calibrations to the standard system were started. Cluster *beta* values were found to be too large, and were thus calibrated with Balaguer-Núñez et al. data. Trends in the data were similar to Balaguer-Núñez et al. and may even be more precise. Both sets of data lead to the conclusion that there is low internal reddening in the cluster.

Introduction

Open cluster M48 (also known as NGC 2548) is a well studied cluster located in the constellation Hydra. In the past, the cluster has only been studied with *ubvy* and *Hβ* filters, only now we have *Calcium* photometry to go along with it. The *Calcium* filter lets in photons with a wavelength centered at 390 nm. With the *Calcium* filter, one can construct a metallicity index, similar to m_1, called *hk*. The metallicity *hk* is found by the equation

$$hk = (Ca - b) - (b - y).$$

This *Calcium* metallicity index is a way to show how chemical abundance affects color in the region of the *Calcium* filter, much like m_1 is a way to show how chemical abundance affects color in the region of the *v* filter. The other goals of the project were to use aperture photometry and profile-fitting techniques to find the reddening, chemical composition (from m_1 and *hk*), age of the cluster, and distance to the cluster.

Observations and Reduction

The data were taken in January 2003 and 2004 using the .9 meter WIYN telescope at Kitt Peak. The images have already been normalized and the bias has already been removed. To process the frames, both aperture photometry and profile-fitting techniques were used. Aperture photometry was used on both field standard star images and cluster images from 2004 only. For cluster images, an original set of 20 stars was selected. These stars were chosen because they were isolated, meaning no other stars or bad pixels were within 20 pixels from the star. The stars were selected while looking at a *y* filter image, so the stars became much dimmer when looking at a *beta narrow* or *Calcium* image. A couple of the stars became too dim in these filters and the magnitudes gained from *phot* had very large errors. To fix this problem, a set of 5 stars was added on to the list to make up for those stars that became too dim. Another problem with the new set of 5 stars was that one star was cut off in some of the later images. The aperture photometry was carried out using the program *phot* located in package *apphot* within IRAF. Information, such as the full width-half maximum value, and the sky sigma value, that are specific to each frame where found using *imexam*. The parameters were then changed for each image and the program *phot* was run. For cluster images, each of the 25 stars had to be found and measured. Once *phot* was done running, it gave out an instrumental magnitude for each star selected.

For the profile-fitting technique, information specific to each frame was found again using the *hselect* command and *imexam*. The first major program to be run was *pstselect*. The program *pstselect* was used because it went through the frame and selected the 50 best candidate stars for the point-spread function (psf). From there *psf* was run interactively on the 50 pstselect-ed stars and a contour plot for each star was looked at and deemed acceptable or not to be used in the psf image. Figure 1 gives an example of a suitable star to be added to the psf. It is suitable because there are no bumps near the edge of the star that could be another star and there are no lines near the star due to other stars or cosmic rays. After all the stars were looked at in *psf*, they were added together to create the point-spread function. After *psf* was run the first time, the programs *nstar* and *substar* were run to remove any faint stars near the selected psf stars. From there, *psf* was run again to insure that a good set of psf stars was chosen. After the final run of *psf*, *allstar* was run. The program *allstar* goes through the cluster image and fits each star to the psf. In doing this, it creates a list of instrumental magnitudes.

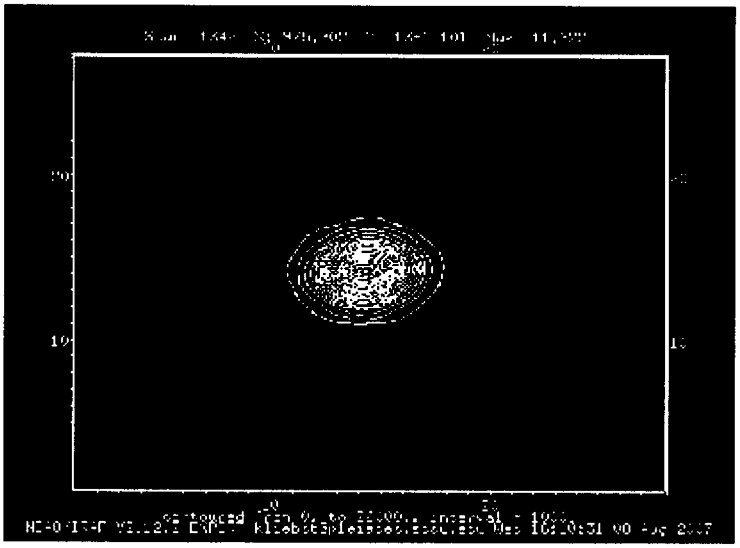

Figure 1: A suitable star to be added to the psf.

Analysis

All the magnitudes generated from the aperture photometry and profile-fitting were instrumental and had to be converted to the standard system in order to compare them with any other studies or do any further work. For these data, the calibration process was started with the *beta* values because they required no extinction corrections. The equation shown below was provided by Dr. Barbara Anthony-Twarog for transforming the *beta* values to the standard system:

$$beta\_std = 1.1405 \cdot beta\_inst + intercept.$$

The slope was determined from the several standard stars and from knowing the equipment very well while working on their main project, NGC 2420. The *beta_inst* value was equal to the *beta narrow* magnitude minus the *beta wide* magnitude. The *intercept* must be determined for each photometric night. The *intercept* was found for a set of standard stars because their *beta_std* values were known. When the same equation was applied to the cluster stars, a problem was encountered. The *beta* values for the cluster stars were far too large. Figure 2 shows the *beta* values for an average of three *beta narrow* frames and three *beta wide* frames taken on the same night. According to a paper done by Balaguer-Núñez et al. in 2005, the values in the rightmost column of Figure 3 should be between 2.5 and 2.8.

Star #	avg. beta narrow	avg. beta wide	beta_inst	1.1405*beta_inst
1	18.470	15.671	2.799	3.192
2	19.947	17.386	2.562	2.922
3	18.885	16.152	2.732	3.116
4	22.253	19.621	2.632	3.001
5	20.975	18.555	2.420	2.760
6	20.156	17.634	2.522	2.876
7	18.514	16.047	2.467	2.814
8	19.832	17.282	2.550	2.908
9	21.899	19.005	2.894	3.301
10	18.027	15.285	2.741	3.126
11	19.643	17.003	2.640	3.011
12	20.333	17.766	2.567	2.928
13	20.215	17.545	2.670	3.046
14	19.643	17.242	2.401	2.738
15	19.226	16.723	2.503	2.855
16	19.566	16.874	2.692	3.070
17	22.144	19.023	3.121	3.560
18	19.080	16.359	2.721	3.103
19	21.060	18.705	2.355	2.686
20	20.563	17.917	2.646	3.017
21	17.903	15.390	2.513	2.866
22	18.666	15.895	2.770	3.160
23	17.351	14.605	2.746	3.132
24	18.152	15.446	2.706	3.086
25	18.011	15.244	2.767	3.155

Figure 2: *beta* of cluster stars

This means that our *beta* values are too big. This problem was most likely caused from the fact that the data were taken on a night that was not photometric. This also means that these data could not be used to calibrate the rest of the data. As a second option, the Balaguer-Núñez et al. paper was used to calibrate the data. Figure 3 shows a comparison in the Balaguer-Núñez et al. *beta* vs *(b-y)* plot (a) and our *beta* vs *(b-y)* plot (b). At first glance, it looked like our trend is opposite of Balaguer-Núñez et al., but the y-axis was just reversed (Balaguer-Núñez et al. *beta* magnitudes got larger toward the origin and our *beta* magnitudes got smaller toward the origin). The data were calibrated by finding stars in common between the current study and the Balaguer-Núñez et al. paper and shifting our data down until it fit with the Balaguer-Núñez et al. data. However, after looking at the current studies data, it was clear that there was less scatter along the trend line than in the Balaguer-Núñez et al. data. This means that the current study's precision and internal errors looked good and that it was more precise than the Balaguer-Núñez et al. data as shown. The low amount of scatter was also a good indication that there was little internal reddening within the cluster. We could not, however, say how much more precise our data was because it was not calibrated with our own data.

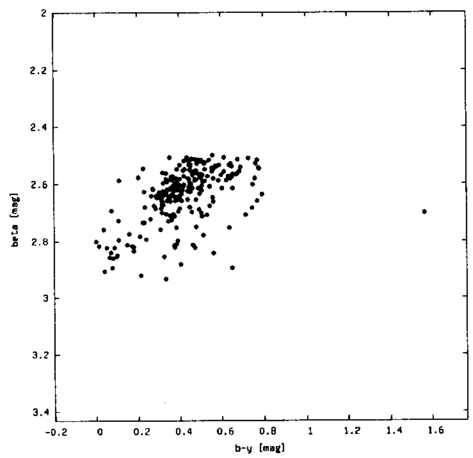

Figure 3a: Balaguer-Núñez et al. *beta* vs. *(b-y)*

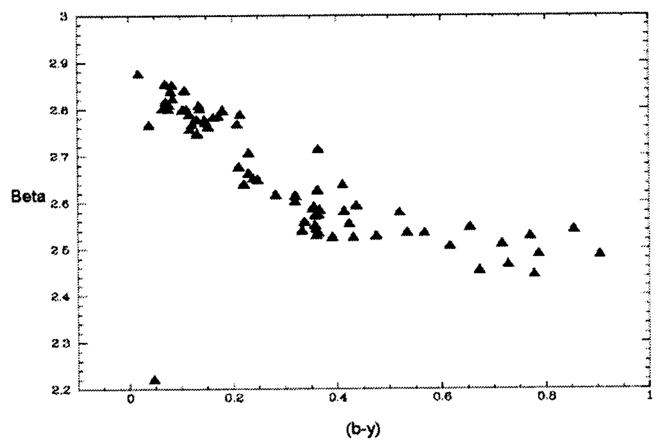

Figure 3b: Our *beta* vs. *(b-y)*

Future Work

The first step for the future of this project is to take more data to use for the *beta* calibrations. More data must be taken using a photometer or by using CCD photometry on a photometric night. This will allow for an actual comparison with the Balaguer-Núñez et al. data. The calibrations for the indices *V*, *(b-y)*, m_1, and *hk* can be completed at this time, only their analysis cannot be completed without a correct beta scale. Once all the calibrations are completed, the reddening for the cluster can be found. The reddening is not expected to be too big from looking at other studies, but it would be big enough to cause errors in the estimates of the chemical composition, age of the cluster, and distance to the cluster.

Conclusions

The results thus far are that the *beta* values obtained from this data were too large to be used to calibrate the rest of the data. This was due to the non-photometric night that the data were taken on. However, the comparison of our data (calibrated with Balaguer-Núñez et al. data) and the actual Balaguer-Núñez et al. data showed that our data displayed the same trend and was possibly more precise than the Balaguer-Núñez et al. data. From our Balaguer-Núñez et al. calibrated data, it was also clear that there was low internal reddening in the cluster. These are hopefully just the beginning of many results to come as work on this cluster is continued in the future.

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References

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