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Photometry of Star Clusters from Mendel Observatory

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Abstract

We have observed four open star clusters and three globular star clusters using Mendel Observatory's 18" Richey-Chrétien telescope. Our photometry data was obtained using non-standard R, G, and B filters. We plotted the results in the form of a Hertzsprung-Russell (H-R) diagram in an attempt to determine the so called "turn-off point" for the observed clusters, which is a strong indicator of age. Due to our limited sample size of stars in each cluster, we were not able to determine the turn-off points and obtain relative ages for the clusters. However, we find that the shapes of our H-R diagrams at fainter magnitudes are consistent with that from other studies [4], despite our much smaller sample size. This project demonstrates for the first time that the Mendel Observatory is capable of obtaining scientifically relevant photometry data [3], specifically of faint stars with a magnitude of 14.65. The methods and techniques we learned from this study will be applied to future related projects involving students and faculty.

Keywords: *Star Cluster, Photometry, H-R Diagram, Mendel Observatory, Turn-off Point*

Photometry is essentially measuring the light captured by a camera, which is attached to a telescope. At the Mendel Observatory, we pointed the camera at different bright star clusters to take images of them. A star cluster is a collection of stars in the same location in the sky, usually assumed to have been born around the same time. Since stars in a single cluster belong to a single population, a plot of their color vs. brightness shows clear patterns related to their different masses. We wanted to do this to see if we could recreate known H-R diagrams, which has never been done at Merrimack College. An H-R diagram [1] is a plot of the color vs. the brightness of stars, where the color is measured by finding the difference between the brightness in two different filters. With the H-R diagrams, we were hoping to be able to see the turn-off point, which could tell us the age of the stars. We were not able to find the turn-off point from either not having enough data or not having accurate enough equipment to pinpoint the turn-off region (maximum range of absolute magnitude); however, we were able to create H-R diagrams and accurately compare them to known H-R diagrams to prove that accurate photometry could be done in the Mendel Observatory. This study was important because H-R diagrams are able to provide a lot of different information about star clusters such as age, color, and temperature. The color of the star is related to the temperature of it, so by measuring its color, we were able to determine the temperature. The only way to do any of the measuring is with accurate photometry equipment and calibration procedures, which we were not certain we had until after the study. There is now a wide range of experiments and studies that are now available in the observatory after we proved that we have viable photometry data.

At the beginning, we were not even sure if we could get H-R diagrams because no one has ever done photometry in the observatory. We had to test and manipulate the telescope, camera and the software so that it would be able to do what we wanted. We had to research and teach ourselves how to do the photometry in our observatory with our equipment. A major issue was that we only had nonstandard R, B, G filters so we had to convert them to standard filters so that we could compare them to their known H-R diagrams. We had to maneuver around the weather (only one in four days was considered viable observing night) and the light pollution from both Merrimack College and even the Boston area.

Materials and Methods

We started by going into the observatory after sunset during a clear night. We used a premade list of semi-bright clusters that we could view from the observatory and whose coordinates were within the telescope's limits. We would then input the coordinates and take images of the different clusters. We used a guess-and-check method on the length of the exposures ranging from one second to twelve seconds for each cluster, depending on the magnitude of the cluster. We were trying to get clear images of each cluster and did not want an image that was overexposed (see Figure 1) or underexposed (see Figure 2), but also could not have too long an exposure because the telescope could shift due to the wind.

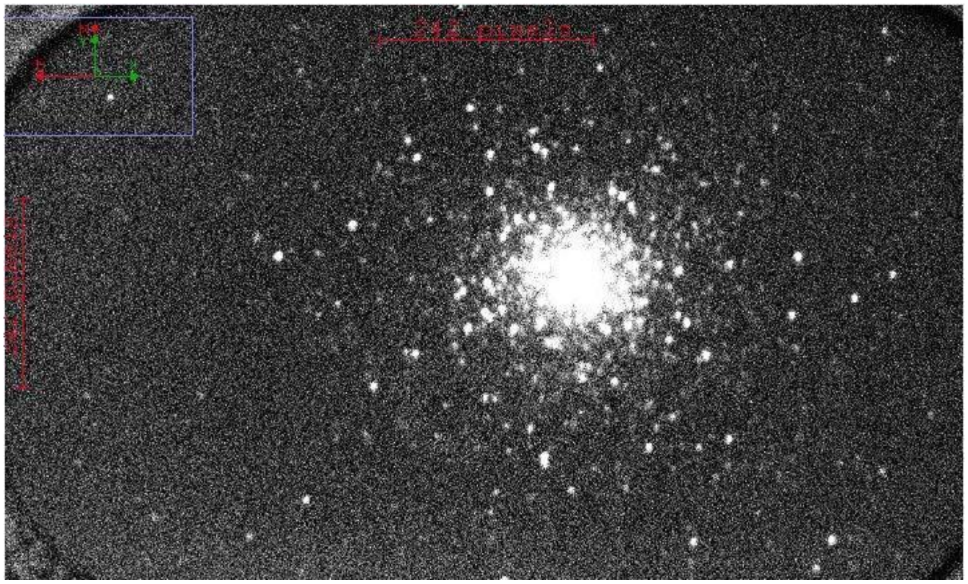


Figure 1: M3 through a red filter, taken at the Merrimack Observatory

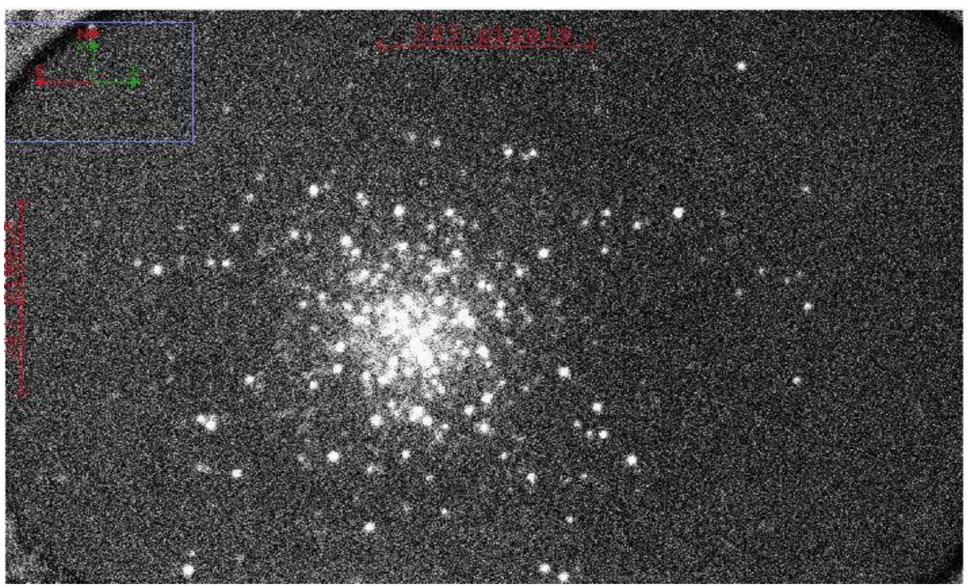


Figure 2: M13 through a green filter, taken at the Merrimack Observatory

We had to take an image of each cluster three different times, each one with a different filter in the camera. We used the software CCDSoft to auto-dark the images, which reduces the thermal noise in an image sensor. We used an established astronomy software program, AstroImageJ [2], to take flat field images (pictures taken through the telescope which has a sheet over it), which reduces the pixel to pixel sensitivity and accounts for the particular optical path in the telescope. We then used AstroImageJ aperture settings to individually select stars in the clusters. We would put the aperture circle around a star and adjust the inner and outer annulus to make them have a larger radius than the aperture. The purpose of the annuli was to find the background noise around each star and then subtract that from the raw inside the aperture circle. As you can see in the top left corner of Figure 3, we are moving the circles to one of the stars.

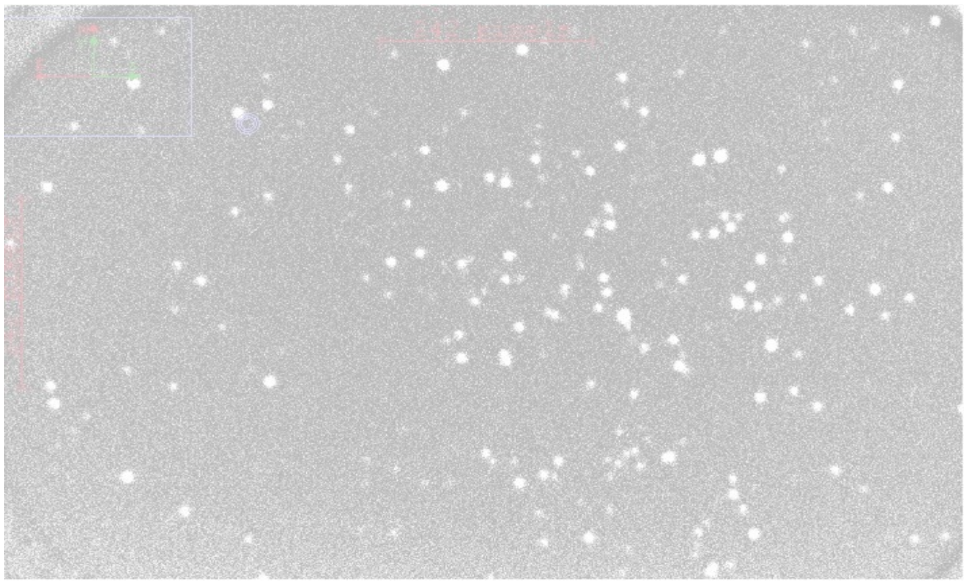


Figure 3: M37 through a blue filter, taken at the Merrimack Observatory

This would give us each star's number of counts on each image. We did this three times for each cluster because of the three different filters that the images were taken with, adding up to over 500 stars.

Once we divided the counts by the exposure time (to get the count rate), we used the equation

$$m_{app}^{b} = -2.5 log(\#counts)$$

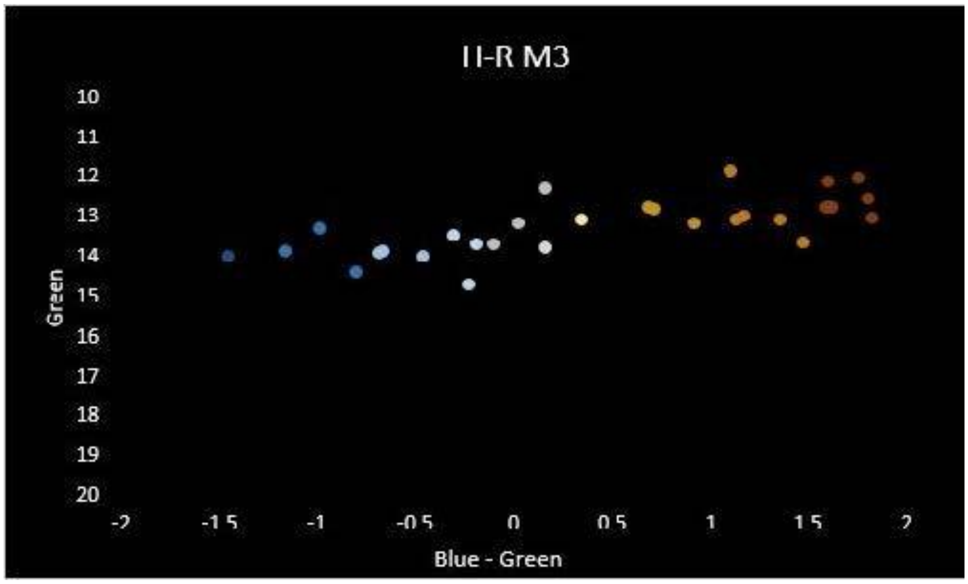
to convert the number of counts to apparent magnitude. Apparent magnitude is the brightness of an object as seen from Earth. To create a standard H-R diagram, we needed to account for the amount of the Earth's atmosphere the light was passing through on that particular night and the fact that we were using non-standard filters by using the equation

$$M_{ab}^{b} = m_b - k_b X + T_b(C_1((m_b - k_b X) - (m_g - k_g X)) + C_2) + Z_b$$

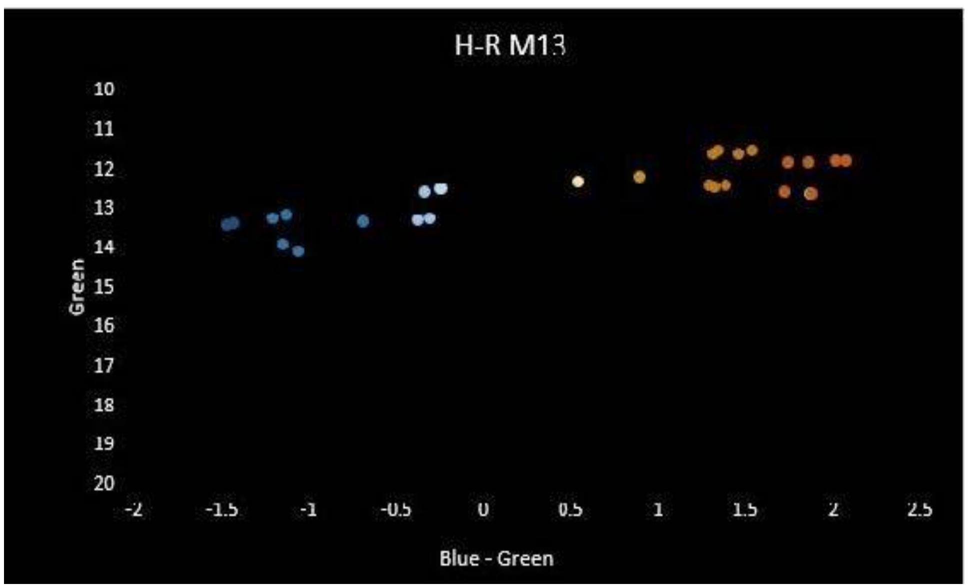
for each different filtered magnitude (in this case blue). To use this equation, we needed to find or look up many of the variables. We found that $m_b$is the measured magnitude we found in the previous equation, $k_b$is the extinction coefficient, X is the airmass, $T_b$is the color transformation coefficient, and Z_b is the zero point of the filter. $C_1$and C_2were found by plotting the color index of standard stars against the observed color index, and $(m_b - k_b X) - (m_g - k_g X)$ is the color index matching T_b. We found all these constants by taking images of so-called "standard stars" whose magnitudes are well-known and comparing them to their magnitudes as measured with our equipment. Once we converted all the blue, red, and green images to absolute magnitude, we could create an H-R diagram by comparing our Green vs Blue-Green for each different cluster. Once plotted, we compared our H-R diagram with known H-R diagrams created at Princeton University [4].

Results

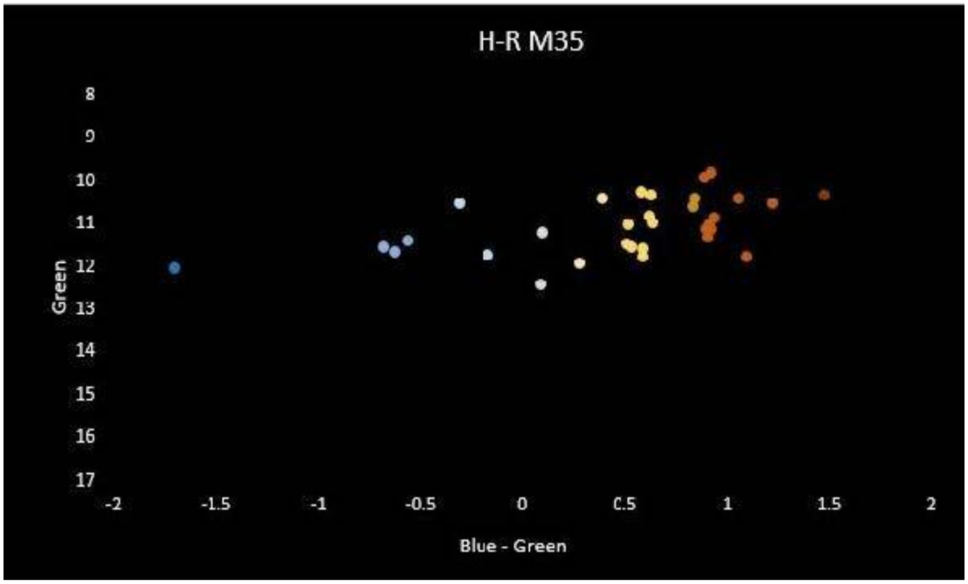
The greatest result from our project is the demonstration that doing accurate photometry in the Merrimack Observatory is possible. When we originally undertook the project, we were not even sure if it was possible to do photometry, but after getting an H-R diagram that is comparable to the Princeton ones, we can say that it went successfully. We found that the Mendel Observatory was able to take images of star clusters using a camera with red, green, and blue filters. We were able to then convert the counts into apparent magnitude and calibrate the magnitude to account for our non-standard filter set. Our data plotted G vs B-G, which was comparable with a study done at Princeton University. However, we were not able to find the turn-off point in the data from either lack of data or our sensitivity range. Our system was able to pick up magnitudes of stars in range of 9-15, so were not able to obtain the full range of magnitudes in the clusters (see Plots 1, 2, 3, and 4). The observing techniques and reduction process will be used in future research opportunities in the Mendel Observatory.



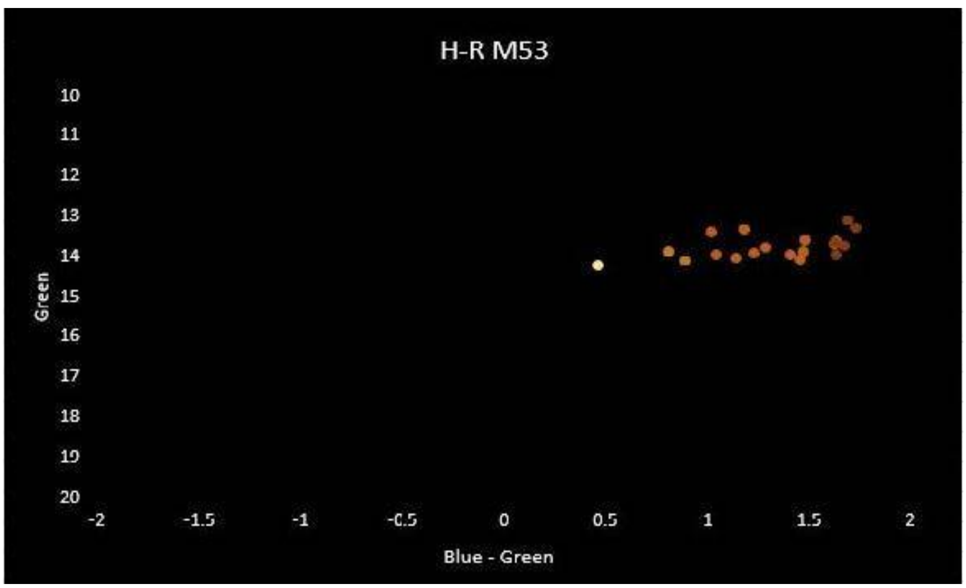
Plot 1: H-R diagram for star cluster M3



Plot 2: H-R diagram for star cluster M13



Plot 3: H-R for star cluster M35



Plot 4: H-R for star cluster M53

References

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