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Astronomy 104 Final Project: HRD diagram of M67

Purpose: To use CCD data of M67, an open cluster in the constellation Cancer, to create a Hertzprung-Russell Diagram (HRD). The HRD will be used to find the pattern of the main sequence and the turn-off point for M67, thereby discovering the cluster's age.

Method: Fellow students took images in three color filters (blue, red, and green) and exposure times varying from 60s to 1200s with the CCD-equipped telescope located on campus. All images have been aligned, flat-fielded, dark-subtracted, and averaged by time (that is, multiple pictures with the same exposure have been added together and their data averaged out into one picture), and these can be found in the folder labeled OneOfEachColor&Time. However, due to time restrictions we were only able to use the images with the longest exposure time, 1200s, in composing our HRD.

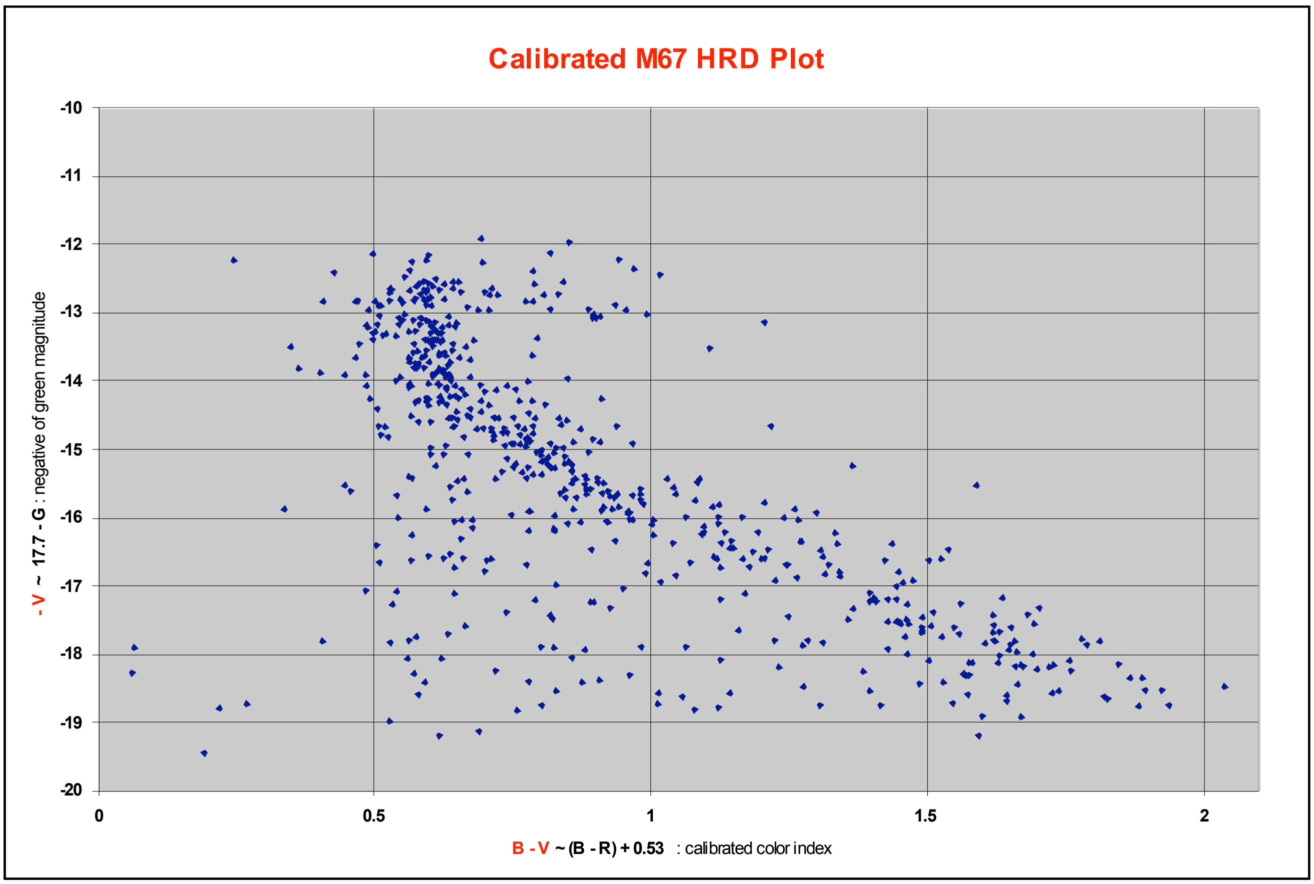
In order to display our data in the standard HRD format, we extracted the data from our three image files (1200s in red, green, and blue) using CCDsoft's AutoAstrometry routine (Research→Analyze Folder of Images→Pre-Analyze). Within the Source Extraction Setup, we changed Seeing to 4.6; Saturation to 40,000; Magnitude to 10; Filter to 2; Size of Pixel to .78; Min. Number of Pixels to 20; Detection to 1.25; Aperture to 8; and left the other parameters at their default setting. We then used "Generate inventory of celestial objects" to create .SRC files with data on each object within the picture. We opened these in WordPad and pasted them to Excel, organized them by magnitude and removed any objects with magnitude less than 4 (likely to be noise) or greater than 20 (oversaturated), as well as any objects that could easily be judged as errors from the pictures. We then resaved these as WordPad .SRC files (we did not work straight from Excel because CCDsoft can't read edited Excel data back into the picture). The final .SRC files are saved in 20mins→Averaged. We then took the x-coordinate, y-coordinate, and magnitude from each color and saved that data in an Excel file (Mag&PosOrig in the same file). From that point, we manually sifted through the files to root out two problematic types of useless data: overexposed stars and non-stellar phenomena (dust, reflections, and other noise) that appeared in the data set; that is, we removed any data that was not present in all three data sets. After the irrelevant data had been eliminated, we created our HRD graph; this graph and its data set may be found in FinalDataSet1 in the same file.

Graphic Format: Our HRD, in the traditional HRD style, defined the y-axis as the luminosity (as given by the negative green constant, negative because magnitudes are higher when the numerical value is lower, and using the negative allows the data to be displayed in a more sensible ascending format) and the x-axis spectral type (as given by blue minus red).

Graph Results: The HRD displays a very apparent main sequence, which is doubled (because many stars belong to binary systems, affecting their luminosity but not their spectral type). Our diagram displays a very clear cut-off point, which is crucial to finding the age of the cluster. However, this diagram is currently ambiguous as to relative position; to determine the actual magnitude of these stars, some would need to be matched to the luminosity and spectral type of known stars. To the lower left of our diagram one can see a smattering of isolated points which, if accurate or relevant pieces of data, would be white dwarves.

Errors and room for improvement: Much of the trouble with doing an HRD of an open cluster is determining which stars actually belong to the cluster. What may appear to be white dwarves or red giants on the diagram could be stars within the same area as the cluster but much farther or closer to Earth. Due to this, they have a different distance modulus which in turn skews their representation on the diagram. The proper remedy for this involves use of parallax to find farther stars, but in this case it is probably safe to simply ignore the lower left corner. The above-mentioned matching of the diagram to actual luminosity can be done using TheSky's data on M67, our data, and the coordinates of stars on our images to confirm the cut-off found in our HRD, but there is only a narrow window of magnitude in which this can be done; a star must be bright enough to be named, but not so bright as to be overexposed (hopefully we have done our job adeptly, and you will be unable to find overexposed stars in the data set). The use of the shorter exposures would also be a great boon to clarity and accuracy, though of course a challenging undertaking.

Our Conclusions: Though there is still much work to be done on this diagram, a great deal of headway has already been made. We think that future students can pick up where our work on the diagram leaves off, and many of the more difficult parts of refining the HRD have been taken care of.



The instructor’s notes:

1. This project needs more than one group of student’s efforts to finish. It needs to be revisited in a later semester.
2. The main unfinished elements are: a. the inclusion of the images taken with shorter exposures, which would add brighter stars, b. the determination of the unknown constants, which should be simple based on a bright star added in part “a”, c. removal of non-star objects (such as dust specks).
3. The plotting of other combinations of colors and color indeces.
4. The instructor’s guess for the constants, based on one known star is V-G=17.7 and also (B-V) - (B-R) =0.53. These relations need to be refined.
5. The presence of many additional field stars under the ‘main sequence’ is not surprising in the star-rich constellation of Cancer.