Constructing and Analyzing an H-R Plot of NGC 559

Maureen Teyssier [1]
Collaborators: Emily Landes [2], Deb Hutchings [3]
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ABSTRACT

A H-R diagram was constructed of open cluster NGC 559, and then analyzed to find the age of the cluster. The age was found to be approximately 8x10^9 years.

1. Introduction

The goal of this project was to construct an H-R diagram of the open cluster NGC 559. (Ra = 01:29:21.6 Dec = +63:16:48) B and V images of the cluster were taken with the 1-meter Nickel Telescope at the Lick Observatory [4]. Photometry was performed over 58 stars in these images, and the calculated apparent magnitudes were plotted as $B-V$ vs V_{mag}. The turn-off point was found, and the age calculated.

2. Data and Interpretations

The images for the Nickel telescope were taken for 45 seconds in the B and V bands. Analysis was done over one image in the V-band, and one in the B-band. 58 stars were chosen for analysis. The flat, dark and bias corrected B and V images were analyzed with a photometry program that sums the DN over a radius defined to be 3σ. This program took the sky level to be the median value for our image. The sky level was calculated this way, instead of the way it had been found previously in this class with a wide annulus around the star. The image contains a large number of stars, instead of just one, so there is a more uniform background brightness in the former, instead of a gradient surrounding a single star. Taking the median of the whole image rather than of one area gives a more statistically accurate measure.

Apparent magnitude was calculated with the basic photometry equation:
$mag_* - magref* = -2.5log(DN_*/DN_{ref*})$,
with mag_{ref*} and DN_{ref*} taken to be the magnitude and DN count of the star NGC 559 #33.

[1]email: teyssier@ugastro.berkeley.edu

[2]email: elandes@ugastro.berkeley.edu

[3]email:debhutch@uclink.berkeley.edu

[4]http://mtham.ucolick.org/techdocs/telescopes/Nickel/nickel.html

This star has $B_{mag} = 12.53$ and $V_{mag} = 11.75$. These numbers were taken from the online Simbad Catalog. [5] In our error propagation calculations these magnitudes were taken to have no error.

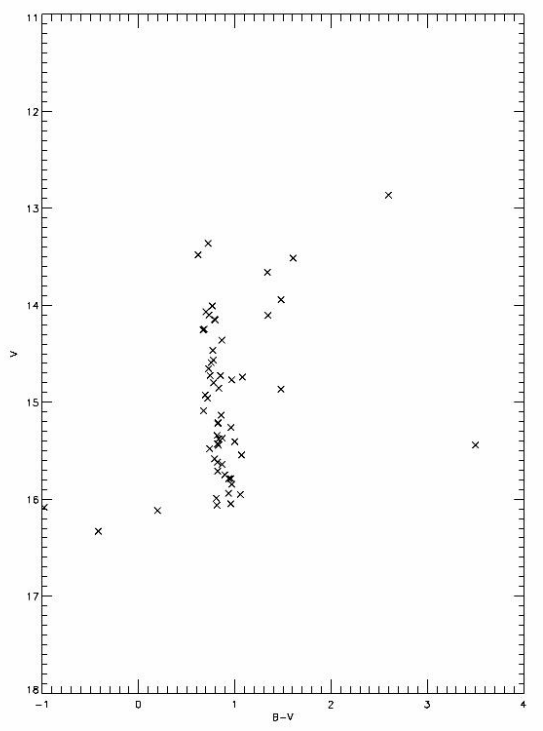

Fig. 1.— Plot of $B - V$ vs. V data from our photometry. The main sequence is clearly shown.

To do our error calculations, we first found the error in the flat field. It was less than one percent, and so was not an important element in calculating the error in magnitudes. Poisson statistics were used to calculate the uncertainty in the DN of the stars. The error was then propagated through the conversion from DN to apparent magnitudes. The Poisson error is: $\sigma = \sqrt{(N_{dn}/g)}$, where g is the gain. High and low values for the gain for the Nickel telescope were reported by the Lick Observatory to be 1.7 and 1.54. For this lab, $g = 1.54$, was used in this error propagation. The error propagation used for converting DN to apparent magnitude simplified to this form:

$$\delta = 2.5 * \frac{\sqrt{\frac{1}{N_{dnstar}} + \frac{1}{N_{dnref}}}}{ln(10)\sqrt{g}} \tag{1}$$

This propagated error is the smallest possible error for this data set.

Figure 1. was analyzed for the turn-off point at which stars depart from the main sequence, and by which the age of the cluster may be found. B-V values for the turn-off point were taken to

[5] http://simbad.harvard.edu

Value	V	$B-V$
Maximum	16.3309 ± 0.0079	18.9402 ± 0.0279
Median	15.1333 ± 0.0046	15.9126 ± 0.0071
Minimum	12.8637 ± 0.0018	14.0852 ± 0.0033

Table 1: Magnitude data calculated from our photometry

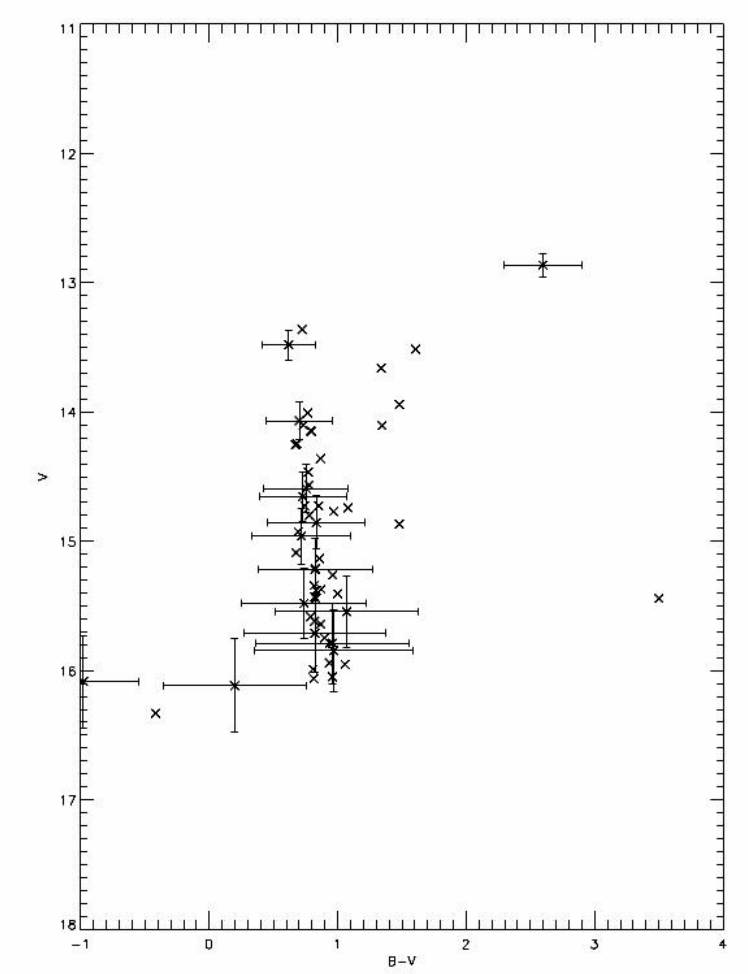

Fig. 2.— H-R plot with error bars shown on every 5th data point. They are 50 times the error calculated for each point in X and Y.

be between 0.64 and 0.70. These $B-V$ values for main sequence stars were taken and compared to M_v values for main sequence stars found in Allen's Astronomical Almanac, and in Carroll and Ostlie's Modern Astrophysics. Shown in Table 2 are the $B-V$ values from our photometry, and the M_v values from these texts.

3. Interpretation

When the images were taken at Nickel, it was noted that some of the brightest stars in the V-band images were saturated, or nonlinear because the pixel wells had started to fill up. However, this time integration was used because it allows the dimmer members of the open cluster to become apparent. So, none of the stars that became saturated in the V-band images were used for analysis. There were few saturated stars, and many other stars to perform analysis on. In choosing stars to do photometry on, groups of stars whose centers were less than, or around 3σ apart on the image, were also avoided. Our thought was that our calculated DN for one star would be affected by light from the other, and so be less accurate.

In correcting the B-band and V-band images from Nickel, the IDL procedure, 'display' was used. This procedure did not initially work because of bad pixels along the edges of the CCD. To correct for this problem, erroneous pixel values along the edge of the flat field image were taken and reset to 1. This did not effect our data because the bad pixels were all along the edge, and not part of the data set analyzed.

The data points in the H-R plot (Figure 2) give a clearly visible main sequence. Main sequence data makes up 91% of the data taken. There are 5 stars on the red giant branch. There are two data points directly above the main sequence. These could be on the horizontal branch, or be blue stragglers. More data, giving a nice horizontal branch, would confirm one or the other. The turn-off point is fairly visible. It is estimated to be between $B-V$ magnitudes of 0.64 and 0.7 and between V magnitudes of 13.85 and 14.

Three or four of the data points seem to show stars not in NGC 559 cluster. There is one very red star, with a $B-V$ of 3.5. This star was thought to be a fluke caused by our photometry program, but our peers got similar results. There are also three blue dim stars on the lower left of Figure 1, that may or may not be members of the cluster. The furthest, with a $B-V$ of -1.0, is mostlikely not.

The effect of reddening was neglected in this lab. It would have effected the B-band more than the V-band, and so have a larger effect on the $B-V$ magnitudes than on the V magnitudes. If reddening was accounted for, the data in the H-R diagram (Figure 1.) would be shifted to the left.

Originally, the distance to the cluster was taken to be 1258 pc. The $B-V$ values for the turn-off point correspond to different M_v values in the tables given by Allen's and C&O, than were determined using 1258 pc. to convert from apparent to absolute magnitude. Explanations for this discrepancy include the followingsources of error: our $B-V$ values are off, (which is likely

V	$B-V$	M_v
14.0	0.64	4.83
14.15	0.70	5.1

Table 2: High and low values of V and $B-V$ from the turn-off point, and M_v corresponding to the $B-V$ from Allen's and C&O

Location	Fraction of Data	Percent of Data
Main Sequence	49/58	84%
Giant Branch	5/58	8.6%
Non-members	4/58	6.8%
Horizontal Branch?	2/58	3.4%

Table 3: Analysis of Figure 1, giving the fractions and percents of the data fitting into each catagory.

because reddening was neglected); the quoted distance is off; or they're both off. After exploring the internet, it seems that the latter-most case is correct; they are both off. Several values for the distance were given by various scientific papers- all were completely different. Distances are often calculated using Cepheid variables- the error in these results is huge. (50%) Due to the enormous descrepancies in reported distances, we decide to concentrate on our $B-V$ values to find the age of the open cluster. So, we used the $B-V$ values around the turn-off point to find what the spectral class of the star would be with a location on the main sequence. Stars around the turn-off point were found to be G5 stars. Using the luminosity and the mass of that spectral type, the energy comsumption of Hydrogen in the star was calculated. The age of the cluster was found from this energy and the luminosity. The age of NGC 559 is approximately $8\text{x}10^9$ years. A diagram that roughly confirms this cluster age can be found in C & O pg. 534.

The distance to the open cluster, NGC 559, could be found, roughly, from our data, by taking the $B-V$ magnitudes for the turn off points, and using a table of values to find the corresponding M_v values for main sequence stars. This data is found in Table 2. Comparing the absolute M_v values to our apparent magnitues from our data gives us a distance to the open cluster ranging from 560 pc to 730 pc. This is a highly inaccurate way to calculate distance. It's basically the result of calculating from approximations. The calculated distance is approximately half the distance reported by Simbad.

Special thanks to Mike Fitzgerald for the B and V images.

REFERENCES

Carroll and Ostlie, *An Introduction to Modren Astrophysics* (Reading, MA: Addison-Wesley).

C. W. Allen, *Astrophysical Quantities* (Bedford Row, LN.).