

Lab 7: The H-R Diagram of an Open Cluster

Due Date: 2007 Nov 27 (after thanksgiving)

1 Introduction: The HR Diagram

In this two-week project you will do *absolute* (not differential) photometry with a CCD to analyze the nature of a cluster of stars, namely NGC 559. You will measure the apparent magnitudes and *colors* of 40 stars in the open cluster and construct an “H–R Diagram”, also known as a “color–magnitude” diagram.

Stars begin their lives burning hydrogen and reside on the “main sequence” in the HR diagram. Your photometric data should reveal the main sequence. As a cluster of stars ages, the more massive stars burn their hydrogen more quickly (in nuclear reactions: $4\text{H} \rightarrow \text{He}$), forcing them to become “giant” stars, eventually becoming white dwarfs, neutron stars, or black holes, depending on their initial mass. Therefore an H–R diagram of a star cluster (Luminosity vs. Temperature) will have a main sequence that is missing its most massive stars, especially the O–type and B–type stars (bluest and most luminous stars). The highest stellar mass that still remains at the “turn–off” from the main sequence is a direct indicator of the age of the cluster of stars. The H-burning lifetime of the stars at the turn-off must be the age of the entire cluster.

Therefore, your construction of an H–R diagram serves as a clock, allowing the cluster’s age to be measured. In this lab you will plot the color–magnitude diagram for an open cluster, and judge its age.

2 The CCD Images

This past sunday, some of you successfully obtained CCD images of the open cluster, NGC 559, that all of you can use. You used the 1-meter “Nickel” telescope at Lick Observatory on 07 Oct 2007. Those CCD images, and a logsheet, are available in the directory:

/home/ay120/ucolick/07oct07/

The logsheet of the observations is in a file: `logsheet.txt`, indicating the available data you may use.

You may use the twilight flats, if available, or the dome flats, as you choose. Choose a level for the bias, and subtract that level from all frames.

As you know, to read `d1028.ccd` you use `readfits.pro`. To read in many images in a row, you may want to convert numbers to their string equivalent:

```
prefix = '/home/ay120/ucolick/11nov07/d'
suffix = '.ccd'
i = 1028
image = readfits(prefix + strtrim(string(i),2) + suffix)
```

Such IDL lines can easily be modified to fully automate processing by placing it inside a loop and changing `i` to an appropriate variable.

3 Photometry in B, V, or I bandpasses

Carry out a calibration of the images, as needed, including bias subtraction and flat fielding. Sky subtraction will occur automatically within your photometry routine, hopefully, with the sky annulus.

Use your aperture photometry routines (or any routine that you've written and prefer) to:

- Measure the magnitudes of 40 stars in both B and V bands.
- Construct an HR diagram for these stars: V vs. B-V

You will need to reference your measured magnitudes to a known value for one star, the “standard star”. A good choice is the star (NGC 559 #33), which is marked with a plus in the image shown.

This star has apparent magnitudes: B=12.53, V=11.75 according to Simbad (<http://simbad.harvard.edu>). Of course, you should double check to make sure #33 is identified correctly on that image (see Figure 2). Note that images called into IDL, and displayed with the “display” command show up flipped upside down.

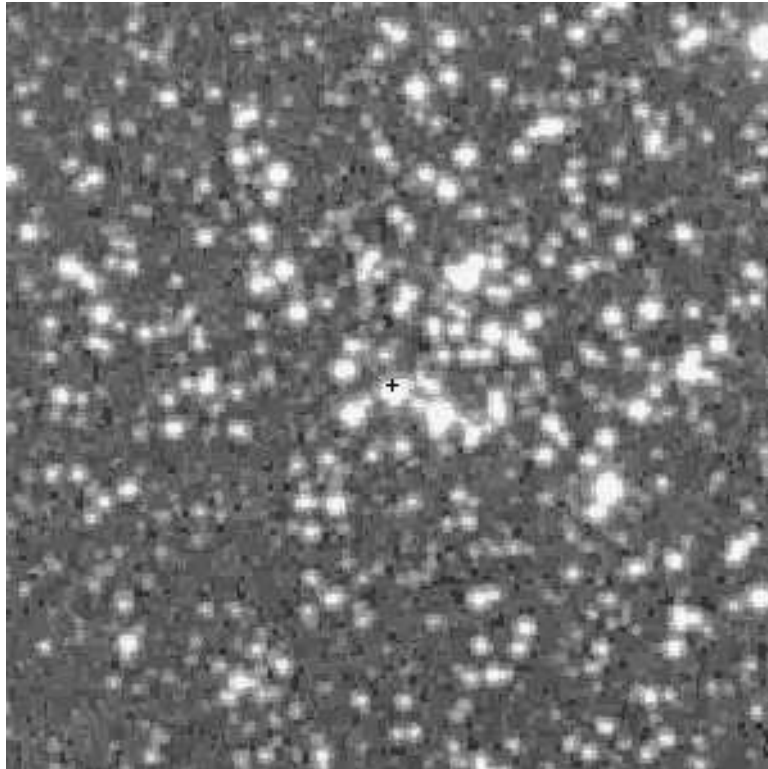


Figure 1: Image of NGC 559 from the famous (but low resolution) digital sky survey, available on the web. The photometric reference star #33 is at center, marked with a “+” symbol. It has $B=12.53$ and $V=11.75$. North is up and East is to the left (same as in the CCD images)

Using this star as a reference, you can determine the B and V magnitudes for 40 stars. You need to use the (log) equation that relates the ratio of the flux to the difference in magnitudes. You may want to check the B and V you determine for one or two other stars against their Simbad values to see if your results are consistent.

3.1 Analysis

- Construct an H-R diagram as V_{mag} vs $B - V$.
- Estimate the uncertainty in your V magnitudes and $B-V$ colors. It is

your choice how you establish this uncertainty estimate. One possibility is to measure two different CCD images (in the same filter) and determine the standard deviation of the differences in your answers.

- Do you detect a Main Sequence? What fraction of the stars seem to be on the Main Sequence?
- What fraction of stars are giants, evolved off the main sequence?
- What fraction of your 40 stars seem to be non-members of the cluster, i.e. chance foreground or background stars?
- What is the approximate color, B-V, and corresponding stellar mass at which the stars have turned off the main sequence? You may want to use any reference book or web page that relates B-V on the main sequence to the corresponding stellar mass.
- Can you think of any other sources of error in your determination of the turnoff mass?
- *Extra Credit:* Take an image of this same cluster, NGC 559, using the Leuschner telescope. What differences in images quality and field of view do you notice?

As a cluster ages, the more massive stars become giants first (see Figure 1). This can be seen dynamically in a *simulation* of a cluster as it ages:

<http://www.astro.ubc.ca/~scharein/a311/Sim/hr/HRdiagram.html>

Click on 100 stars and then click on ‘‘evolve’’. The age is at lower left.

- What is the approximate age of the stars in the cluster?

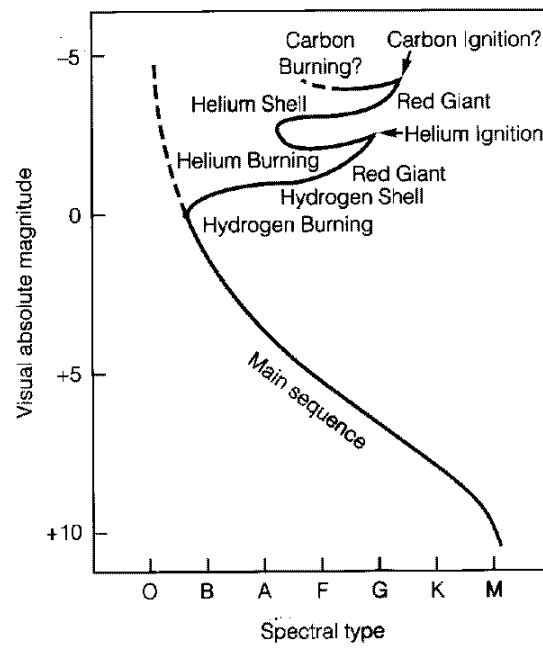


Figure 2: The HR Diagram, showing the turnoff of the main sequence.