Notebook Due: Nov. 19, 2025 by 11:59 p.m.
Writeup Due: Nov. 21, 2025 by 11:59 p.m.

Submit on BurinLearn. If the time between your observing time and the final write-up is less than 7 days, then you have up to 7 days after your observations to turn in your final writeup and up to 5 days after your observations to turn in your notebook.

4.1 Introduction

The goal of this lab is to produce a color-magnitude diagram of a star cluster and interpret it to determine the properties of the stars and approximate distance to the star cluster.

In this lab, you will observe the Galactic open cluster Messier 52 using the UCLA 24 inch telescope. As a backup in case observations with the UCLA 24 inch telescope is not possible, you can use data of the Galactic open cluster NGC6791 taken previously by the Hubble Space Telescope.

You will observe or obtain data from the central region of your cluster in multiple filters, and then you will use Python to reduce the images and perform aperture photometry on the stars. You will use multiple exposures in each filter to estimate the errors on your photometric measurements. You will then process these measurements to produce color-magnitude diagrams for the cluster.

This lab will extend the techniques you have learned and used in the class to date. The write-up you produce will be analogous to a scientific research paper. This lab will have more weight on your final grade than other labs. Be sure to allocate sufficient time for the analysis and write-up.

4.2 Observing with the UCLA 24 inch telescope

4.2.1 Observation Preparation

target	R.A. (2000)	dec (2000)
M 52	23h 24′ 48″	+61° 35′ 36″

Review and refine your observation procedures before arriving at the telescope.

Use the http://skyview.gsfc.nasa.gov advanced query interface to generate a finder chart for your target(s). Be sure to select a field of view appropriate for the observations below — the focal length of the telescope is 384.1 inches, the CCD is 3326 by 2504 pixels, and the pixel size is 5.4 μm. Note the center of the field on the finder chart, so that you may identify it at the telescope.

Select an appropriate Landolt standard star (as well as one backup star) for photometric calibration.

4.2.2 Observations

You will take science observations in 4 pointings around the center of M 52. For each pointing, you will position the center in one corner of the CCD. Obtain data in the V and R filters. Use a sufficiently long exposure time so that you detect many stars in the field, but not so long that you saturate on the brightest stars. In order to estimate your photometric errors, obtain at least three exposures in each pointing and band. More data will allow you to reduce the uncertainty in the average value of a given measurement.

For accurate photometry, you will need to offset the telescope and obtain blank-sky exposures in each filter. You will also need to observe a photometric standard star in each filter.

You will need to flat-field your data, so you will take dome flats at the end of your observing. Be sure that you have obtained the appropriate dark-frame measurements.

4.2.3 Data Reduction

As in the previous lab, you should dark-subtract, flat-field, and sky-subtract all of your science images.

You will also use a similar procedure for obtaining photometric measurements of each star. Use the photometric standard star to derive the magnitude zero points (be sure to include them in your write-up).

Measure the flux for each star you are able to detect in your fields. Develop a numbering scheme for your stars, or use an existing numbering system from the literature. (If you develop your own numbering scheme, be sure to include labeled images in your write-up.)

4.3 Back up program: Obtaining and using HST data

4.3.1 Learning about HST and WFC3

Before downloading the data from HST, read about the WFC3 instrument and the types of data files that are available by reading the HST WFC3 Data Handbook: https://hst-docs.stsci.edu/wfc3dhb. Read Chapter 1 and Chapter 2 for an overview of these topics. Some important things to pay attention to are: what are the filters on WFC3-UVIS? Which ones are closest to V and R filters? What file type should you use for science?

4.3.2 Downloading data from the MAST Archive

There are several interfaces for downloading HST data. The one we will use is called MAST https://mast.stsci.edu/portal/Mashup/Clients/Mast/Portal.html. Before using this, be sure to read the help pages about the user interface, how to make a query, and how to download data. After getting a sense of how the system works, query for data from NGC6791. Use the search filters on the left side to select only HST data from the WFC3-UVIS instrument, then select the HST wide-band instrument filters closest to V and R on the right side. Be sure that the two filters are the same field of view. You only need one pointing of the star cluster (you can use the visualization on the right side to help select the pointing).

4.4 Analysis

Compute the average magnitudes for each star in each filter. Estimate the error in this measurement using the standard deviation of the flux measured in each image.

Remember, if you combine N independent measurements x_i (each having uncertainty σ) to compute the average μ,

$$\mu = \frac{1}{N}\sum_{i=1}^{N} x_i, \tag{1}$$

then the uncertainty in μ is not σ, but rather

$$\sigma_\mu = \frac{\sigma}{\sqrt{N}}. \tag{2}$$

This is because the measurements are independent and add linearly, therefore their errors add in quadrature:

$$\mu = \left(\frac{1}{N}\right) x_1 + \left(\frac{1}{N}\right) x_2 + \ldots + \left(\frac{1}{N}\right) x_N, \tag{3}$$

$$\sigma_\mu^2 = \left(\frac{1}{N^2}\right)\sigma^2 + \left(\frac{1}{N^2}\right)\sigma^2 + \ldots + \left(\frac{1}{N^2}\right)\sigma^2, \tag{4}$$

$$= \left(\frac{1}{N}\right)\sigma^2. \tag{5}$$

Plot the apparent V magnitude vs. the $V - R$ color for your stars, including error bars.

4.4.1 Magnitudes from HST data

If you are using HST data, you will need to convert between the units of your aperture photometry to magnitudes. First determine the units of you images, then read the calibration of the UVIS zero points at https://www.stsci.edu/hst/instrumentation/wfc3/data-analysis/photometric-calibration/uvis-photometric-calibration. Using these zero points, convert your measurements into Vega magnitudes. Remember to check that your units are the same as that from the zero points. If they are not the same, then convert the units so you can use the zero points.

4.5 Discussion

What features in the color-magnitude diagrams of the cluster can you identify? Compare the apparent magnitude of your main sequence to the absolute magnitude of a published color-magnitude diagram, e.g. from a textbook. Can you estimate the distance to the cluster? Discuss the sources of error in this estimate.

4.6 Write-Up

The format should be like a published scientific article. It also needs to convey enough information that someone else who has never been in our lab could understand what you did and could even duplicate the experiment. An important part of this is publishing all of the measurements of your stars' flux, magnitudes, and uncertainties. Each person must produce his or her own write-up. This means that you can work in teams, and collaborate on the reduction and analysis of the data, but you must use your own words when producing the paper. Many journals now accept electronic submission where you email your article in LaTeX form. It is common to many fields of science and mathematics. You may use either LaTeX or MS Word or similar word processor.

Most astronomical papers have five major sections, and this will be a good pattern for you to follow. In some cases the headings may not be exactly right, so you can modify them as necessary, but the spirit should remain. Use the style guide given at the end of the Solar Lab.