

Name \_\_\_\_\_

Date \_\_\_\_\_

Lab Partner(s) \_\_\_\_\_

**Project Score**

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# MEASUREMENTS OF STELLAR MAGNITUDES AND COLORS

**PROJECT LEVEL:** Intermediate

**PROJECT GOALS:** Students will measure apparent magnitudes and colors of stars. From these measurements, the absolute magnitudes and temperatures of the stars will be determined. The data used are from the University of Iowa Rigel telescope, and will be analysed with the MaximDL program.

**IMAGE DIRECTORY/LIST:** Lab Images/StarsAndGalaxies/BV\_Photometry

## 1 INTRODUCTION

A simple measurement of the **APPARENT MAGNITUDE** at two wavelengths is often sufficient information to determine many important properties of stars. To make these measurements, optical astronomers typically use **FILTERS** to capture only the light from specific wavelengths at a time. The filters we will use for this project select the **BLUE** (B) and **GREEN** (V, for visual as the sun's peak wavelength is green and our eyes are most sensitive to green) parts of the spectrum. Other interesting filters (unused here) are **RED** (R), **NEAR-INFRARED** (I), **HYDROGEN-ALPHA** (H) filter which select only the strongest Hydrogen Balmer line, or the **OXYGEN III** (O) filter which selects the strongest spectral line of ionized Oxygen.

In this observing project, you will study an open cluster (also referred to as a galactic star cluster) and observe several stars using the blue (B) and visual (V) filters. You will measure the apparent magnitudes in B and V light (" $m_V$ " and " $m_B$ "; these apparent magnitudes are also just referred to as "B" and "V") and calculate the *color index* (B-V). From the color index, you can determine the surface temperature of the star and its spectral class. In addition, given an independent value for the distance to this star cluster, you will calculate the absolute magnitude M. Finally, with knowledge of the temperature and absolute magnitude, you will be able to plot the stars on a Hertzsprung-Russell diagram, and determine what kind of stars they are.

In addition to the intrinsic value of this experiment, this project will also provide you with training in measuring stellar magnitudes with Rigel data and the MaximDL program. This training will open the door to many possible experiments for the research project in the last half of the semester.

### 1.1 Magnitude System

The magnitude system is the standard way of expressing stellar brightness. Magnitudes have been discussed in lecture. Review the definitions if you have forgotten them, and recall the concepts of *apparent magnitude* and *absolute magnitude*. The concepts of apparent and absolute magnitude will be important in this project. Examples of apparent and absolute magnitudes for some familiar stars are given in Table 1.

**TABLE 1 - TABLE OF APPARENT AND ABSOLUTE MAGNITUDES FOR SAMPLE OBJECTS**

Source	$m_v$ or V	Mv
Sun	-26.5	4.8
Sirius	-1.43	1.4
Vega	0	0.6
Polaris	2.0	-3.2

## 2 BASIC STELLAR PROPERTIES

The spectrum of radiation from a star resembles that of a hot, opaque object (a “blackbody” in physics terminology) described by Kirchoff’s first law and Wien’s Law. As such, the color of a star is determined by the temperature in its photosphere. There is a simple relation between observed color and surface temperature.

### 2.1 SURFACE TEMPERATURE

Once the apparent magnitudes  $m_B$  and  $m_V$  are found, the **COLOR INDEX (B – V)** (which is just  $(m_B - m_V)$ ) can be calculated. For B-V in the range 0.0 to +1.5, the relationship between B-V and the surface temperature can be written as:

$$T = \frac{6901K}{(B - V) + 0.70}$$

The color index can also be used to determine the spectral type using Table 2 at the end of this document.

## 2.2 ABSOLUTE MAGNITUDE AND DISTANCE

There is a relationship between the apparent magnitude ( $m$ ), the absolute magnitude ( $M$ ), and the distance to a star ( $d$ , in parsecs),

$$m-M = 5 \log(d/10)$$

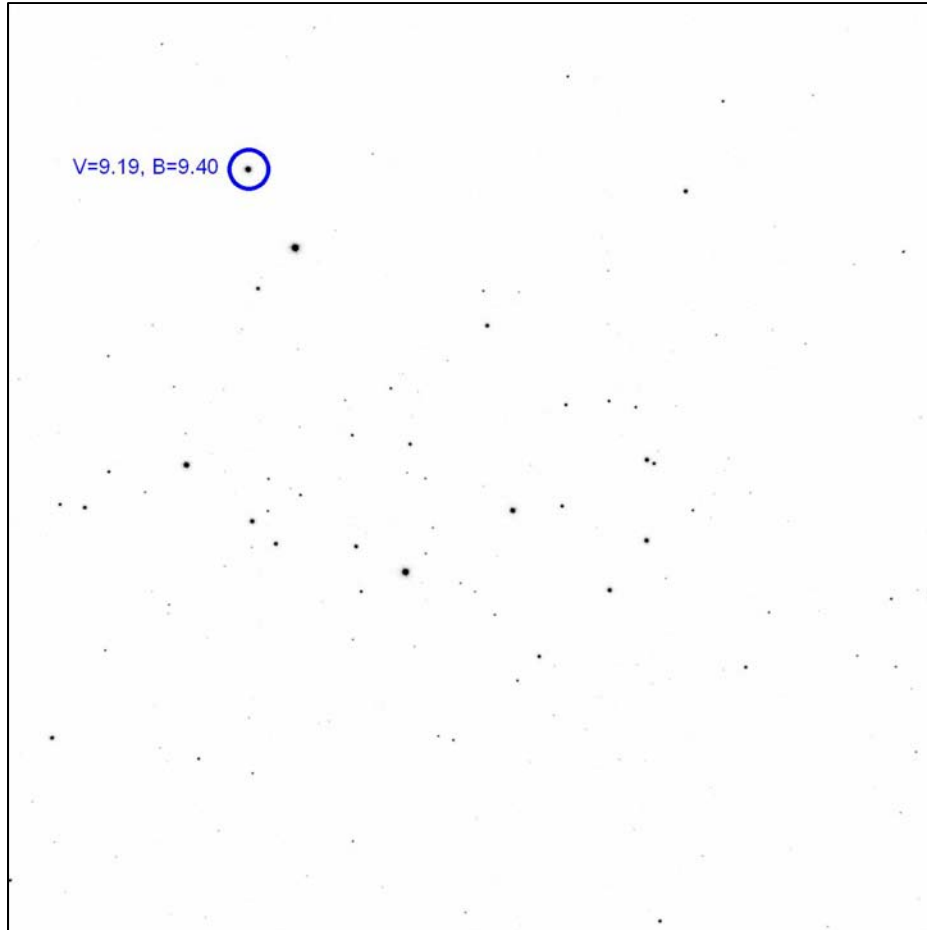
Normally in astronomy, one uses known values of  $m$  and  $M$  to obtain the distance  $d$ . In this project, we will do things a little differently and determine  $M$  for several stars in a star cluster, given a measurement of  $m$ , and an independent value for  $d$ . In this case  $M$  is given by

$$M = m - 5\log(d/10)$$

Although the absolute magnitude can be defined for any color, it most commonly is the visual absolute magnitude  $M_V$ . In the remainder of this project,  $M$  will mean the absolute magnitude in the visual filter.

## 3 IMAGE ANALYSIS

In this lab, we will measure properties of the open star cluster NGC 1342. This star cluster is in the constellation of Perseus, not far from the famous star Algol (Beta Persei). **The distance to NGC 1342 is 540 parsecs.** A reference image of NGC 1342 is in the directory for this experiment (given at the beginning of this document), and is reproduced as Figure 1 for your convenience. The reference image should be used for orientation purposes, and you should indicate the stars for which you do photometry measurements.



**Figure 1. Reference image for NGC1342**

### **3.1 Image Calibration and Basic Photometry Instructions**

Before you can use your images of NGC 1342 to determine properties of individual stars, you must first **CALIBRATE** your image. You may recall from previous projects that the telescope images are measurements of photons striking the CCD chip, resulting in a number of digital (ADU) counts. Calibration is the process by which you “teach” MaxIM to convert ADU counts into magnitude units. The star we will use as a calibrator is HIP 16461. It is the uppermost bright star in the upper left quadrant of the Figure 1, indicated with an arrow. **The  $m_B$  and  $m_V$  magnitudes (or “B” and “V”) for HIP 16461 are 9.40 and 9.19, respectively.**

Run MaxIm. Load both the V and B images for NGC 1342. You may need to adjust the histogram. Recall that you do this moving the colored arrows on the Screen Stretch window. When the image is clear, and you are confident that you can see all of the stars, click on View/Information Window to open the information window, and then press the Calibrate

button in order to prepare for photometry. You should see a box appear underneath the Calibrate button with several selections that we will later use to calibrate the program.

### 3.1.2 How to do Photometry

You will be doing **DIFFERENTIAL PHOTOMETRY** on this cluster of stars. Differential photometry is done by first making a circle around a star and adding up all of the ADU counts within that circle. The sky background brightness is subtracted from this total, and the resulting ADU counts are set equal to a magnitude. The magnitudes of other stars in the field are determined relative to this star by comparing ADU counts. Fortunately, programs such as *MaxIm* remove most of the tedium of photometry by doing the arithmetic for you.

In order to do photometry properly, you must set up your cursor to check the correct radius. When the information window is active, your cursor will look like a targeting crosshair surrounded by three circles in the active image window. By pressing the right mouse button, you can select the size of the centroid Aperture, Annulus, and Gap Width. The centroid is the area of interest for the cursor. You want to set the Aperture size to be just larger than the largest star you are measuring (note: not necessarily the largest star on the image itself). The Annulus is used to calculate the average background brightness of the image so its size determines how much is averaged. The Gap Width determines how far away from the central aperture the annulus is placed so that the background is measured. Check the image and the reference chart to determine the largest star you will be measuring. Move the cursor over that star and select an Aperture size. Adjust this until the centroid circle is just larger than that star. You do not want the circle too large, as it will then be difficult to accurately record the magnitudes of smaller stars. Consult your instructor if you are unsure if your centroid circle is too large or small. For the purposes of this lab, a Gap Width value of 3 and an Annulus value of 2 are adequate.

### 3.1.3 Calibration of Reference Star

Now you need to calibrate *MaxIm* for photometry. In the area underneath the Calibrate button, you have three Magnitude Calibration selections, *Intensity*, *Exposure*, and *Magnitude*. All three are needed, but only one (*Magnitude*) requires information not found from the image itself. Use the information for HIP 16461 given above.

Enter the magnitude given for the reference star in the Magnitude box. Next, click the Set from FITS button next to the *Exposure* box. This sets the exposure time from the FITS header in the image. Now, click the Extract from image button next to the *Intensity* box. Move the crosshairs on to the image of HIP 16461 and click on it. This extracts the intensity level from the image, and sets the star you clicked on to the magnitude you entered in. If you started with the V image, make sure that you enter the V magnitude here. You have now set your reference star.

(Note: Make sure you do not adjust anything in the magnitude calibration area again, else you will have to recalibrate and re-measure every star.)

### **3.2 Measuring Magnitudes ( $m_B$ and $m_V$ ) for Stellar Cluster Members for B and V images**

Select 5 stars from the cluster, making sure the stars you select are visible in both images and are not overexposed. Clearly indicate the stars you have measured on the cluster reference image. You should choose a mix of bright and faint stars.

Once calibrated, measuring magnitudes with Maxim is easy. Just move the crosshairs onto the star of interest, centering the crosshairs on the stellar image. The magnitude of the star appears in the information window.

Now load the B image. Select the same calibrator and set of five stars from the cluster. Calibrate the image using the steps described above and record the B magnitudes for the same 5 you chose in the V image.

### **3.3 Obtaining Temperatures and Absolute Magnitudes**

Using the equations in this document and the information in Table 2, determine the temperature (see equation in Section 2.1), spectral type (see Table 2), and absolute magnitude ( $M_V$ ) for each of your stars (see Section 2.2). Tabulate your data in Table 1. In most cases, the values you measure for the color will not directly correspond to a value for the spectral class from Table 2. In these cases, do your best to interpolate between the given values. Record your estimates for each star in Table 1.

### **3.4 Plotting Your Stars on the H-R diagram**

Using data from Table 1, plot your 5 stars on the Hertzsprung-Russell diagram in Figure 2. Identify the type of star for each of your 5 stars, i.e. spectral class M supergiant, spectral class A Main Sequence star, etc. Note these in the box under Table 1.

**Table 1**

Star	$m_B$ (B)	$m_V$ (V)	$(m_B - m_V)$ (B-V)	T(K)	Spec. Type	M
1						
2						
3						
4						
5						

**CALCULATIONS****TABLE 2 - RELATIONSHIP BETWEEN B-V COLOR INDEX AND SURFACE TEMPERATURE AND ABSOLUTE MAGNITUDE OF MAIN SEQUENCE STARS**

Spectral Type	$m_B - m_V$ or (B-V)	$M_V$	$M_{bol}$
O5	-0.28	-5.8	-10.0
B0	-0.25	-4.1	-6.8
B5	-0.13	-1.1	-2.6
A0	0.00	0.7	0.1
A5	0.10	2.0	1.7

F0	0.22	2.6	2.6
F5	0.34	3.4	3.4
G0	0.47	4.4	4.3
G5	0.57	5.1	5.0
K0	0.72	5.9	5.8
K5	0.98	7.3	6.7
M0	1.17	9.0	7.8
M5	1.32	11.8	9.8

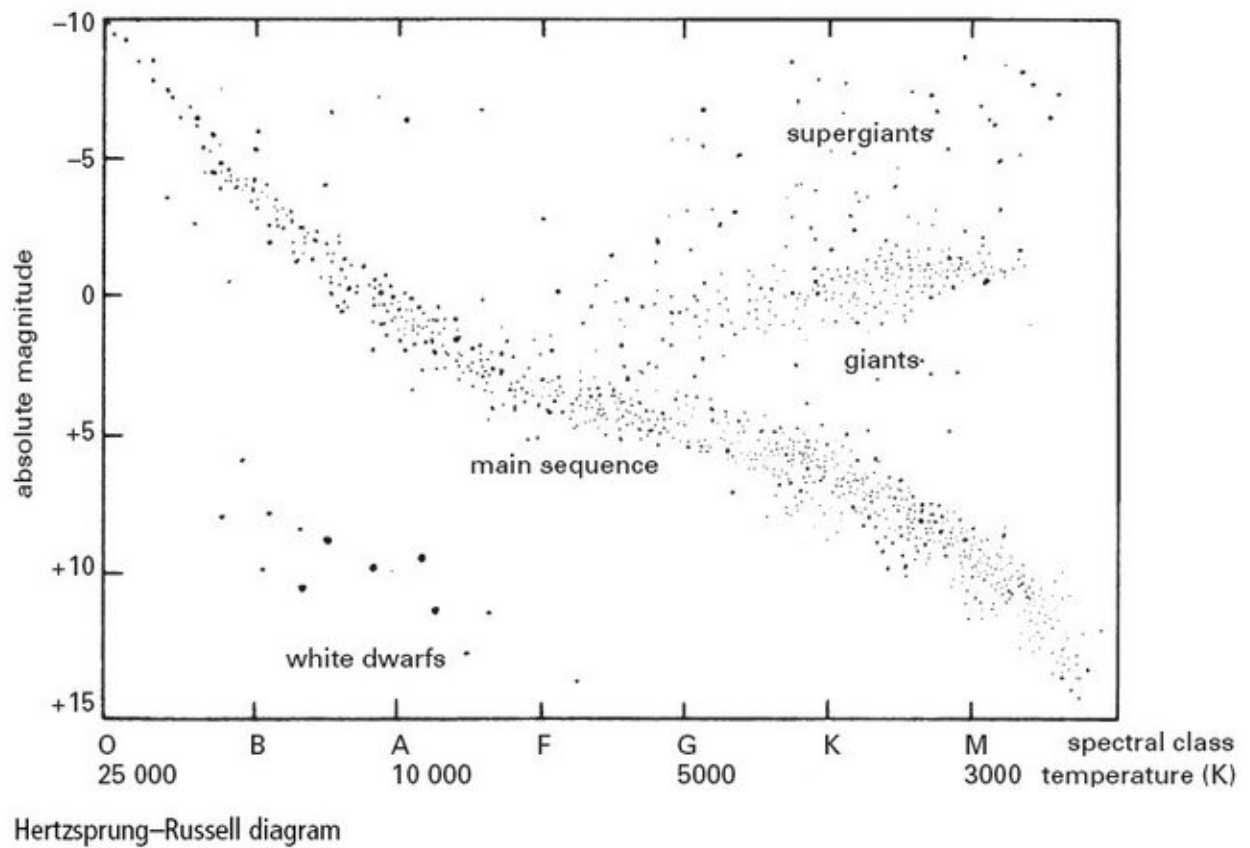


Figure 2