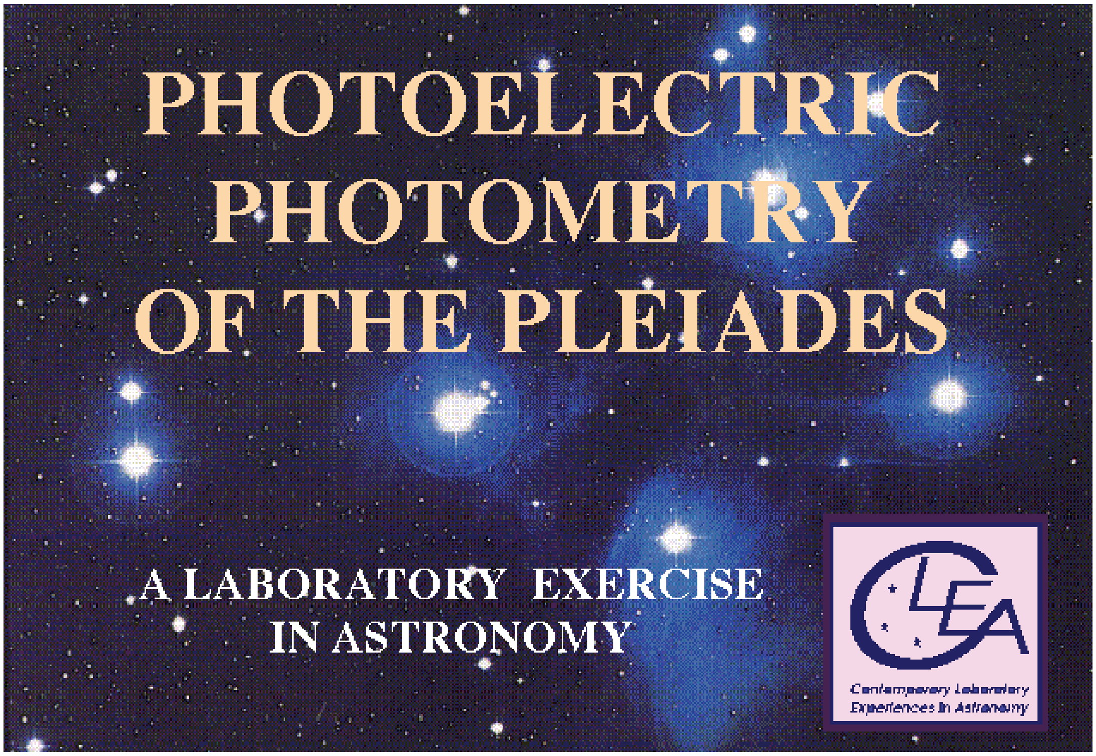
name

CLEA Photometry



The computer program was written and designed by
Department of Physics
Gettysburg College
Gettysburg, PA 17325
Telephone: (717) 337-6028
email: clea@gettysburg.edu

The lab instructions are written and edited by
Esther L. Zirbel
Department of Engineering Science and Physics
College of Staten Island
Staten Island, NY 10314
Email: zirbel@postbox.csi.cuny.edu

This Lab is a continuation of the previous lab on the Photometry of the stars in the Pleiades. In the previous lab, you determined the magnitudes of stars by measuring the diameters of the stellar images and correlating them to the magnitudes of standard stars. Following that, you plotted a Hertzsprung-Russell Diagram. In principle, you will do the same type of exercise again, but with three major differences. The computer will give you a sense of using a telescope to obtain your data; it will measure the diameters of the stars for you and convert that to apparent magnitudes. So all the tedious work will be done for you. Guess what this means — you'll have more time to think about the data, do some real science and come up with clever interpretations.

Part I: Main Sequence Stars

(Budget **half an hour** for part I)

1) Define the following quantities:

   a) Apparent Magnitude

   ____

   ____

   b) Absolute Magnitude (also explain how it relates to Luminosity)

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   ____

   c) Distance Modulus

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   ____

2) What is a main sequence star? What do all main sequence stars have in common, and how do they differ from proto-stars, white dwarfs, brown dwarfs, giants and super-giants?

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3) Draw the Hertzsprung-Russell diagram of "main-sequence stars"

   - Place the clear plastic over the HRD further along in this exercise.
   - Use the ruler to trace both x and y-axes.
   - Label and scale the x-axis the same as the graph paper, but number the scale of the y-axis of the plastic overlay to range from -10 (at the top) to +20 (at the bottom).
   - Label this new y-axis **ABSOLUTE V MAGNITUDE, M_V.** (Note that the y-axis of the original HRD is **APPARENT** Magnitude.)
   - Leave the plastic laying on the graph paper so you can use the grid lines.
   - Plot these calibration stars on the plastic overlay.

Table 1 (adapted from Allen, Astrophysical Quantities)

Absolute Magnitude	B-V	Spectral Type
-5.8	-0.35	O5
-4.1	-0.31	BO
-1.1	-0.16	B5
-0.7	0.00	AO
2.0	0.13	A5
2.6	0.27	F0
3.4	0.42	F5
4.4	0.58	GO
5.1	0.70	G5
5.9	0.89	KO
7.3	1.18	K5
9.0	1.45	MO
11.8	1.63	M5
16.0	1.80	M8

3) You just plotted the Hertzsprung-Russell diagram of main sequence stars. For these stars we know their colors and absolute magnitudes – after all that's how we identify stars as main-sequence stars. For your program stars you will determine the **apparent** magnitudes, but for the current stars you plotted the **absolute** magnitudes. What information do you suspect you might obtain from the difference in the apparent and absolute magnitudes of main sequence stars?

____

Explain your answer

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Explain why you were asked to plot stars for which you already know the absolute magnitude?

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Part II: Data Acquisition

Budget **half an hour** to read and follow the next two pages.
(You basically have to learn the program and take sky readings)

Budget **half an hour** to complete Table 1.

1) Basics and Program Operation

- **Log in**
  Position the mouse cursor over PHOTOMETRY, and double click the mouse button. Enter information. Press TAB after each name; then OK, then YES. Click START on the menu bar.

- **Apply for time on a larger telescope**
  Click on Monitor to change to Finder mode. Go to the Telescope menu and click on Request Time. Select the 1m and/or the 4m telescope. If you get time, click on Telescope again and chose a telescope: the 1m or 4m telescope. **Otherwise repeat this step in 10 minutes!!**

  [In real life, large telescopes are highly oversubscribed. Therefore, if you were a professional astronomer, you would have to apply for time on a competitive basis. This is just to give you a feeling of what real astronomers have to deal with — this aspect has been included in the "Virtual Telescope" program. If you are "lucky," the program will grant you time, otherwise re-apply 15 minutes later. I know this is nasty — but who said these labs do not test your patience — and thank the producers of this program for not including "virtual clouds" in this program.]

- **Open the Dome; Turn on Tracking**
  Click on **DOME.** Click on **TRACKING**. Tracking counteracts the effect of the earth's rotation thus causing the stars to "stand still".

- **Move the telescope**
  Click on **N, E, S, W** to move the telescope with respect to the sky. The **SLEW RATE** control adjusts the speed with which the telescope moves. Try various settings of the **SLEW RATE** and move the telescope around in all directions.

- **Finder Scope and Telescope Views**
  All telescopes have a finder scope (the additional small telescope located at the side of big telescopes). The finder gives you a much larger field of view, so you can identify which part in the sky you are looking at. Generally the center of the field of view of the finder (*i.e.*, the red square) tells you where your big telescope is pointing. Click on **MONITOR** to switch between the **FINDER** and **INSTRUMENT** (the telescope).

- **Photometer Aperture**
  The **PHOTOMETER** mode (obtained by clicking on **INSTRUMENT**) shows a **CLOSE-UP** of the star field. The small red circle in the center of the field of view is the ***photoelectric aperture*** and is the portion of the sky being examined by the photometer. The desired star must be carefully centered within the aperture. (Note that the telescope has to be in the **PHOTOMETER** mode to take readings.)

2) SKY Readings

When looking at the sky, you might have noticed that the night sky is somewhat bright — this is actually much worse in the New York area than almost anywhere else in the US. The brightness of the star corresponds to the contrast between the measured brightness of the star and the night sky. Thus we will need to measure the brightness of the night sky and then subtract that from the observed brightness of the star. To measure the sky brightness, do the following:

- Move the telescope until the aperture (red circle) is free of any star.
- Select a FILTER. (U, B, or V - they cycle when clicked).
- Set SECONDS to 10 seconds, and INTEGRATIONS to 5.
- Then click on TAKE READINGS and wait for the reading.
- The computer will take a series of integrations and display the individual 5 photon counts in the RAW COUNT BOX on the right, and also take the average of all 5 readings. The number in the RAW COUNT BOX actually corresponds to the number of photons ser second that are measured within that particular aperture (the red circle). So this quantity is a measure of the energy per second per area – thus it is the FLUX.
- Repeat the procedure for each filter.

Table 2

Filter	Mean Counts	Signal/Noise	Magnitude
U			
B			
V			

Why do you suspect you are asked to take FIVE readings rather than 1?

Why do you suspect each of the five readings is different?

3) **Take Readings of the Program Stars**

- Click on **SET COORDINATES** and enter a desired **RIGHT ASCENSION** and **DECLINATION** of each star. The Right Ascension is displayed in hours, minutes and seconds, and the declination in degrees, minutes and seconds. Then click **OK.**
- Move the telescope so that the star is in the center of the aperture. [Use the directional controls, **N, E, S, W**, and adjust the **SLEW RATE.**
- Select a **FILTE**R (U, B, or V - they cycle when clicked).
- Set **SECONDS** to 10 seconds (or less); Leave **INTEGRATIONS** at 5.
- Click on **TAKE READINGS**, and wait for 5 integrations. The computer then takes the average and transforms the mean counts to magnitudes (as described below).

  [If the observations take too long, change the integration times. Use shorter integration times for bright stars, but make sure the **S/N RATIO** does not drop below 100. If it still takes too long re-apply for time on a larger telescope.]
- Record the magnitude in **each** filter into Table 2.
- Turn off the tracking and close the observatory when you are done with all filters and stars.

The computer makes it easy for us. It automatically converts the **COUNTS PER SECOND** (after correcting for the sky background) to **MAGNITUDES** as follows. It first subtracts the background sky photons from the "counts per second", so that you are left with the "energy per second per area" of the star itself. This is the "FLUX" of the star.

We now want to transform this quantity to "magnitudes", just because is more meaningful to us. It is based on "what our eyes see". Since our eyes register light **logarithmically** (sorry – that's life!) the transformation is a little messy, although you have probably seen this formula before:

$$m - m_{STD} = -2.5 \times \log \frac{flux}{flux_{STD}}$$

So, the computer does this conversion for us (it takes the logarithm of the background subtracted counts and multiplies them by -2.5). However, this is not the only step. In the last exercise you had to use standard stars, i.e., stars for which you already know the magnitudes. The computer is doing all that work for you, so you only need to explain what "standard stars" are used for.

Table 1: Photometry Data

Star	RA			Dec			U	B	V	U-B	B-V
	hr	min	sec	deg	min	sec					
1	3	41	05	24	05	11					
2	3	42	15	24	19	57					
3	3	42	33	24	18	55					
4	3	42	41	24	28	22					
5	3	43	08	24	42	47					
6	3	43	08	25	00	46					
7	3	43	39	23	28	58					
8	3	43	42	23	20	34					
9	3	43	56	23	25	46					
10	3	44	03	24	25	54					
11	3	44	11	24	07	23					
12	3	44	19	24	14	16					
13	3	44	21	24	35	00					
14	3	44	27	23	57	57					
15	3	44	39	23	27	17					
16	3	44	39	24	34	47					
17	3	44	45	23	24	52					
18	3	45	09	24	50	59					
19	3	45	27	23	17	57					
20	3	45	28	23	53	41					
21	3	45	33	24	12	59					
22	3	46	26	23	41	11					
23	3	46	26	23	49	58					
24	3	46	57	24	04	51					
25	3	47	29	24	20	34					

Part III: Plotting the Data

Plot your data onto last week's HRD that is reproduced on the next page.

Do either (1) or (2)

1) The "Manual Option"

This option is easier – all you need to do is plot the data from Table 3

- Calculate B-V and U-B. Type it into Table 3
- Plot the HRD below, i.e. insert the data points (V and B-V) from Table 3.
- Take a differently colored pen and plot B and U-B. (The x-scale is U-B, and the y-scale B)

2) The "Excel Option" (if you chose to do this check with your instructor)

In this option excel will plot the data for you and calculate the luminosities, temperatures and radii. The catch is that you will have to answer the questions below.

- Open the Excel File called "Photometry 2" on your Computer. (If it is not there go to http://inanna.apsc.csi.cuny.edu/zirbel/labs, right-click on "Photometry 2 Spread Sheet", and download that file onto your computer.)
- Type the Values of U, B and V into the Excel spreadsheet.
- Get a printout of sheet 3 and 1. Click on "Chart1" and look at the Hertzsprung-Russell diagram. Get a printout of this graph. Click on "Chart2" and "Chart3" and get a second and third printout
- Attach Sheet 1, Sheet 3, and Chart 1, 2 and 3 to this Lab

a) Take the B-V versus V plot of the computer and copy the points to the HDR on the next page. You need to do this because the HRD has to be drawn at the same scale as the first plot, i.e., the one on the transparent paper.

b) What is the spread in luminosity (in solar units) of your data?

____

c) What is the temperature of the bluest and the reddest stars in Chart1?

____

d) What is the radius (in solar units) of the largest star and of the smallest star?

____

e) Circle those stars on Chart1. What are the luminosities and temperatures of those stars?

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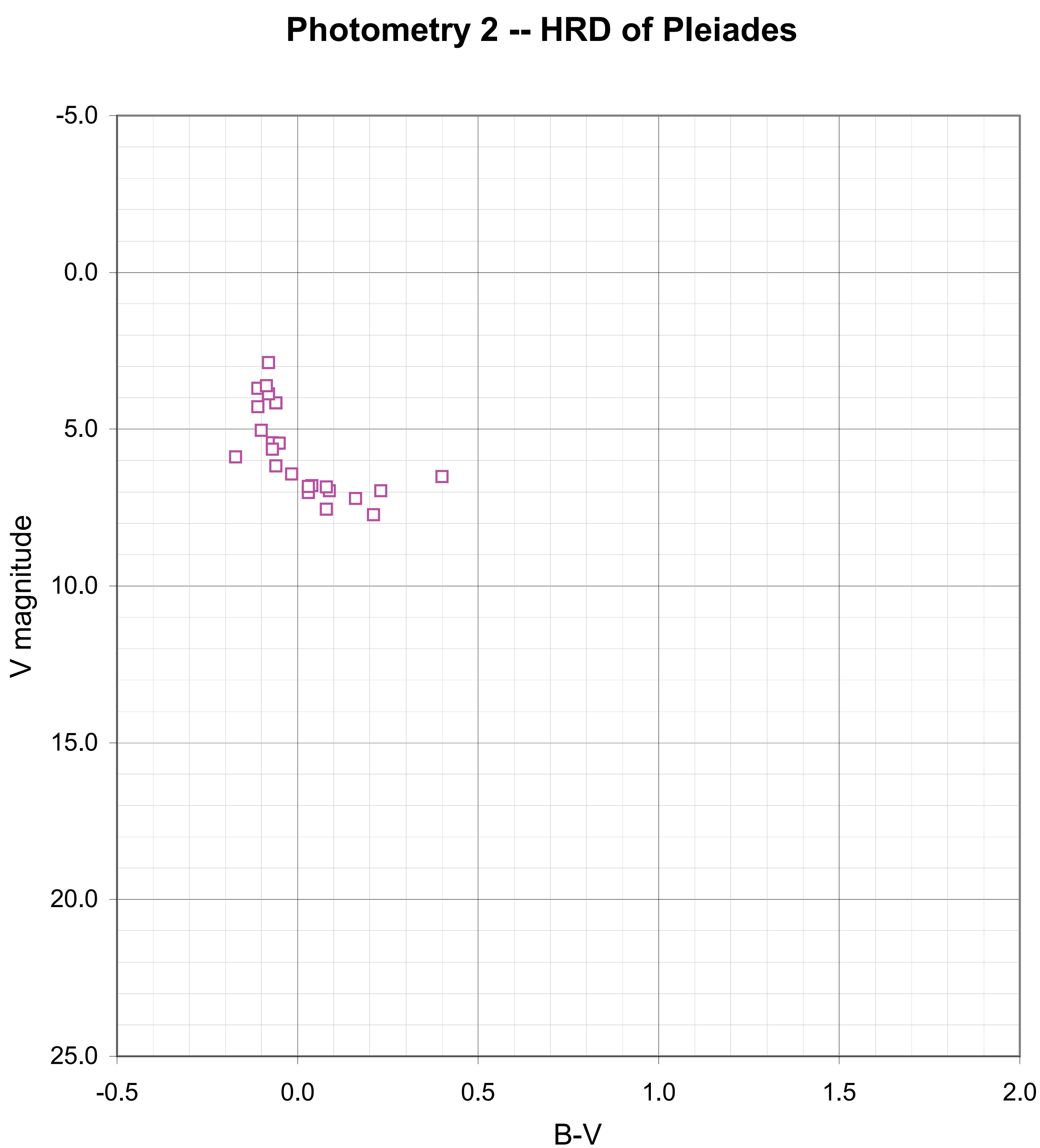
f) The Sun has a luminosity of $1L_{<}$ and a temperature of 5800K. Draw the Sun into Chart1.

Squares are Data from last Lab



Part IV: Analyzing the HRD

1) Oddballs in the Hertzsprung-Russell diagram

Table 4

Star Number	RA	Dec	V	B-V	Type
					red giant
					red giant
					red giant
13	$3^h\ 44^m$	24^o 35’			

- Look at the HRD of B-V versus V. Identify the Main Sequence and label it clearly.
- Identify three possible red giant stars by their RA and DEC. Circle them on the HRD.
- Consider the star near RA $3^h\ 44^m$ and Dec 24^o 35". It seems curiously out of place with respect to the main sequence. What type of star might this be? Circle this star in the HRD and write your answer into Table 4.

2) Temperatures and Colors

Explain how the B-V index is correlated to temperature.

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Explain how the U-B index is correlated to the temperature.

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When would you prefer plot the V vs B-V plot, and when would you prefer the B vs U-B plot?

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3) Determining the Absolute Magnitudes

Compare the HRD of Pleiades to the HRD of the standard stars. The scales of both plots should be the same. The only difference is that the y-axis of the first plot is "Apparent Magnitude" (small m) and the y-axis of the second plot (the plastic overlay) is the Absolute Magnitude (big M). Slide the plastic overlay up and down (keep the y-axes precisely parallel and on top one another) until the main sequences of both plots are aligned (the cool red stars in the lower right of your *paper* graph are quite scattered and may not fit very well). When the patterns are matched, each star of the combined main sequence can be described either in terms of m (by reading the y-axis on the graph paper) or M (by reading the y-axis on the plastic overlay).

- On the paper plot, write the values of the absolute magnitudes next to the apparent magnitudes.
- Read the offset in the y-axis between the two plots to the **nearest 10th** of a magnitude.

The offset is: ___________ ± ____________

4) Determining the Distance to the Cluster

This offset (i.e., m-M) is also known as the "DISTANCE MODULUS." Let's understand the reason. Since the absolute magnitude of a star is defined as the magnitude the star would have if placed at a distance of 10 parsecs, the difference between the absolute and apparent magnitude will give you [the log] of the distance [remember – magnitudes are defined as the log of the fluxes].

The distance modulus is: $m - M = 5 \times \log_{10}(d) - 5$

To solve this, add "5" on both sides, divide by "5" and take the anti-log. The distance in parsecs is:

The distance is: $d = 10^{\left(\frac{m_V - M_V + 5}{5}\right)}$ [this means **ten to the power of** $\frac{m_V - M_V + 5}{5}$]

- Convert the distance modulus to distance: __________________________ parsecs
- Convert to light years: ________________________ light years
- Our Galaxy is about 100,000 light years in diameter. Pleiades is a relatively close cluster to our solar system. Think about the number you just calculated. Is it roughly in the right order of magnitude? If this is NOT the case suggest of what could be wrong.

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5) **Comment on the accuracy of the distance.** What is the main source of error in the distance?

6) **Estimate the error in the distance.** Make two rough calculations of the lower limit and upper limit of the offset and calculate the overall range in the distance.

7) **Critically comment on this method that we call "main sequence fitting".** Make suggestions of how to reduce the error in the distance. Would you need to observe on larger telescopes? Why/why not? Would it really help if you got more accurate magnitudes for ALL stars? Would it really help if you used computers – would this make the measurements more accurate? Would you need more observations? Of which stars in particular – of bright or faint or red or blue stars? Why?

Lab Report

(one page MINIMUM!!)

Answer the following points (write short paragraphs on each point)

- State the objective of the lab
- Mention which telescope you used or should have used (why that?)
- Summarize how the program determined the apparent magnitudes of the cluster stars
- Explain how you used standard stars to determine the absolute magnitudes of the stars
- Explain how you would have determined the luminosity and temperature of those stars
- Explain how you determined the distance to the whole cluster
- Comment on the accuracy of the distance
- Comment on this method – what could be done better in the future?
- For extra credit, explain how you could determine the age of the cluster (read section 13-3 in your book)