CLEA/VIREO

PHOTOMETRY OF THE PLEIADES

Starting up the program

The computer program you will use is a realistic simulation of a UBV photometer attached to a small (*diameter=0.4 meters*) research telescope. The telescope is controlled by a computer that allows you to move from star to star and make measurements. Different filters can be selected for each observation, which allow you to observe over different wavelengths of light. The computer also does much of the busy work needed to convert photon counts into apparent magnitude and provides an estimate of the quality of the collected data.

You will use this instrument to collect data on 24 stars in the region of the Pleiades star cluster. The apparent magnitudes will be measured for each star, over two different filters. *We will assume all of these stars are approximately the same distance away.* This is a necessary and reasonable assumption because all of the stars are members of the same cluster. If we did not make this general assumption, the absolute magnitudes of the stars would also depend on their individual distances, an effect we cannot easily take into account in this lab.

Double click on the "Vireo" icon on the start screen.

Go to File... Login and enter your names. You don't need to enter a table number.

Go to File... Run Exercise... Photometry of the Pleiades

Go to Telescopes... Optical... Access 0.4 Meter

Open the telescope dome by clicking the *Dome* switch (See Figure 1) to *Open* and turn the volume off on the computer if it isn't already.

Switch the *Telescope Control Panel* (See Figure 2) to *On* and a new window will pop up, the *VIREO Optical Telescope Control Panel*. You now have control of the telescope.

By default, the telescope is not tracking, so you should see the stars beginning to drift through your field of view as the Earth rotates. You can determine which way they are moving by looking at the *North, South, East, West* controls to the left of the field of view and just below the tracking button (See Figure 3). Note that *East* is on the left-hand side of the window and *West* is on the right-hand side of the window.

Think about which way the stars are moving, and why this is happening.

Which way does the Earth Rotate? Which way do the stars drift?

On your answer sheet, fill in the answers to these questions under the heading (*Part I: Understanding the Photometer*).

After you've answered these questions, turn the tracking on by clicking the *Tracking* button (See Figure 3).
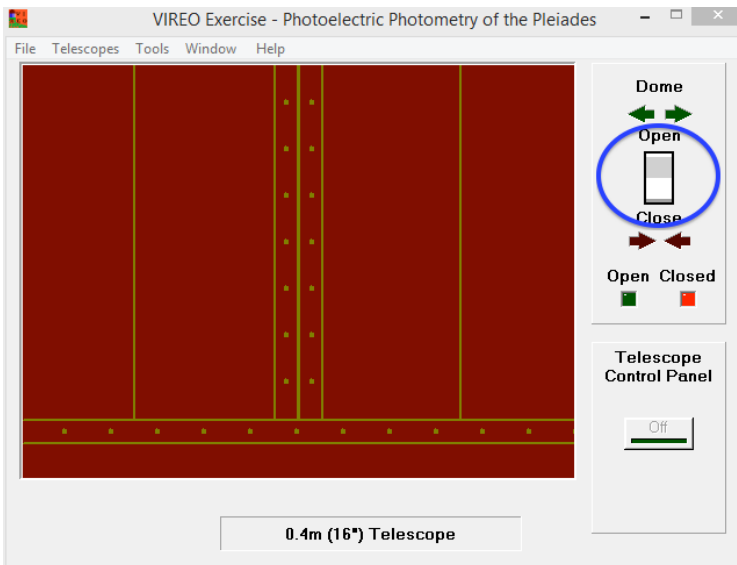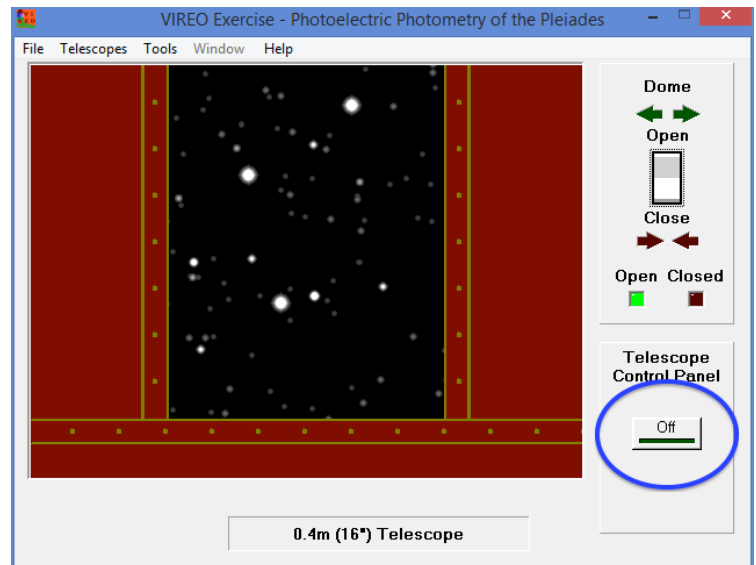

FIGURE 1

FIGURE 2

Taking Measurements with the Photometer

Before we can begin to measure the brightnesses of the stars in the Pleiades with the *Photometer*, we need to calibrate the telescope. We do this by taking measurements of the brightness of the background sky. This will allow us to separate the photons emitted by our stars from photons that are emitted elsewhere and scattered through the sky.

To access the Photometer, slide the button under *View* to *Telescope* (See Figure 4 - Blue). Then, click *Access* under *Instrument* (See Figure 4 - Pink) which will bring up another window, the *VIREO Photometer Control*.

The red circle in the center of the field of view is called the *Aperture*. The Aperture indicates the portion of the sky where the Photometer is pointed. Make sure there are no stars in the Aperture when taking sky readings.

Double check the slider under *Reading* is set to *Sky* (See Figure 5 - Blue) and that the slider under *Filter* is set to *B* (See Figure 5 - Pink). Under *Integration Seconds* set the
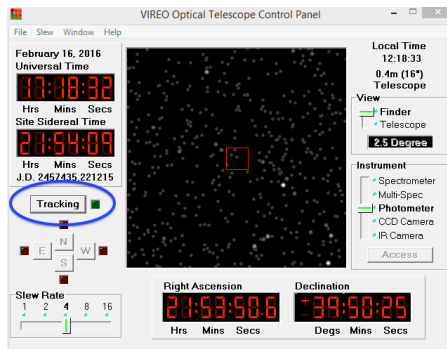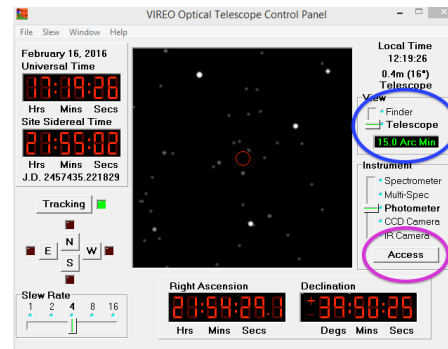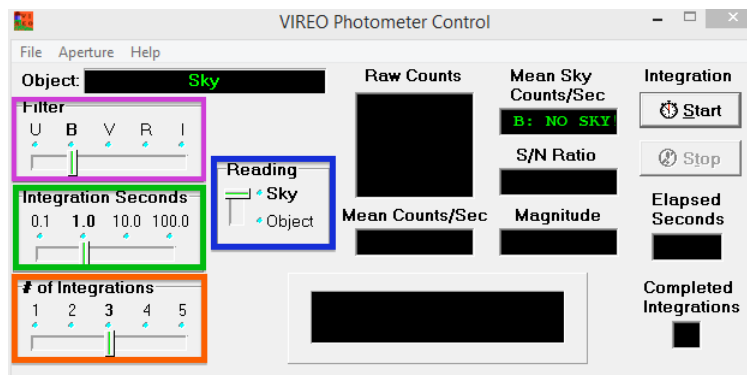

FIGURE 3 FIGURE 4

FIGURE 5

slider to *10.0* (See Figure 5 - Green); Integrations means how long the Photometer will take a measurement. Under *# of Integrations* set the slider to *5* (See Figure 5 - Orange); this is how many times the Photometer will take a measurement.

We are now ready to take Sky measurements. Press the *Start* button under *Integration* (See Figure 6 - Green). The Sky readings will be displayed under *Raw Counts* as each measurement is completed (See Figure 6 - Blue).

Records these values along with the *Mean Counts/Sec* value (See Figure 6 - Pink) on your answer sheet under the heading (*Part II: Calibrating the Photometer*).
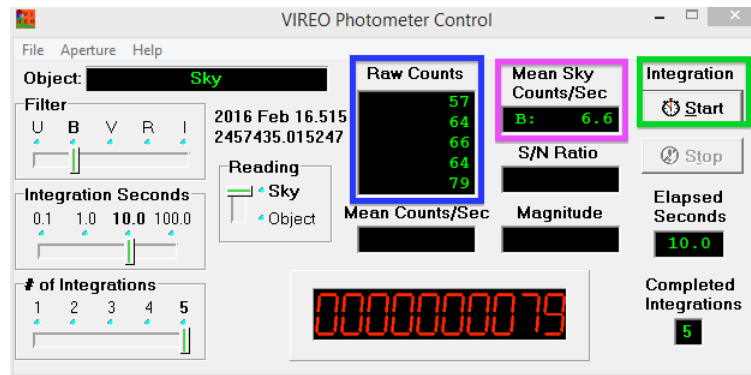
Repeat this process for the *V* filter.

FIGURE 6

OBSERVING THE PLEIADES

Now that we have calibrated the Photometer, we can take observations of the Pleiades and determine the brightnesses of the stars within the cluster. On your answer sheet, in *Part III: Photoelectric Photometery of the Pleiades*, you will find the *Data Sheet* with a list of 24 target stars to observe. Let's begin observations for *Star 1*.

Under the *VIREO Optical Telescope Control Panel*, go to *Slew... Observation Hot List... View/Select from List* and select Star 1 from the list which is displayed. The program will then ask if you want to slew to the *RA* and *Dec* coordinates of this star. Verify that the coordinates displayed match the coordinates listed for Star 1 in your Data Sheet.

If so, press okay and begin slewing the telescope to the coordinates for the first star. This may take a moment as the program is simulating a real telescope, and the slewing process can be slow. Double check that the tracking is on.

Once the telescope has finished slewing and the star is centered in the aperture, change the *Reading* slider in the *VIREO Photometer Control* window to be set to *Object* (See Figure 7). Be sure the filter is set to B, the Integration Seconds is set to *10.0*, the # of Integrations is set to 5, then press Start.
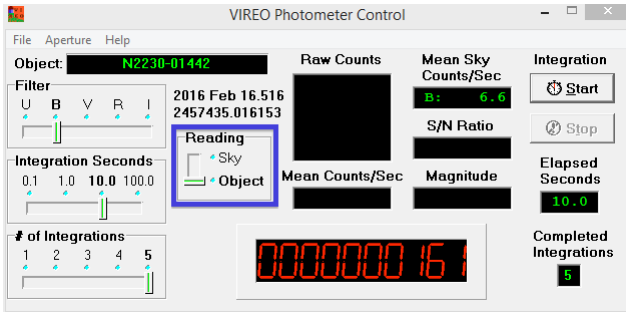

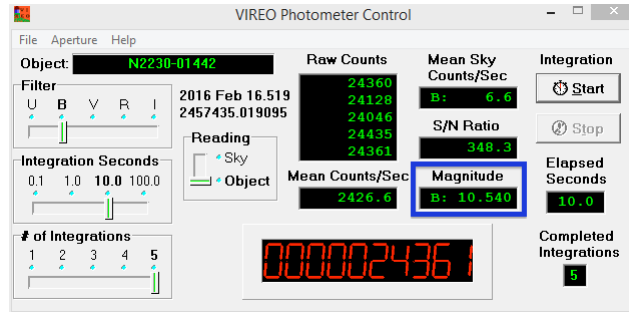FIGURE 7   FIGURE 8

Once the integrations are complete, record the value listed under *Magnitude* (See Figure 8) onto your Data Sheet (ex: *B: 12.035*). Repeat the process for the *V filter* by changing the filter from B to V.

After measuring a magnitude for V and recording it in the Data Sheet, subtract the B and V magnitudes which you have measured and record the answer in the *B-V* column of your Data Sheet.

Repeat this process for all 24 stars. Proceed to the next star by selecting the *Observation Hot List* under the *Slew* menu. For every target, you will take 5 integrations in the *B Filter* and 5 integrations in the *V Filter*, each for *10 seconds*. Calculate *B-V* as you proceed through the list. Some of the calculated *B-V* values will be negative.

Determining the Distance to the Pleiades

Now we will make a *Color-Magnitude Diagram* using these data. A Color-Magnitude Diagram is similar to a Hertzsprung-Russell (HR) diagram, but we plot colors and magnitudes rather than temperatures and luminosities. This can be done since the color of an object provides information about the object's temperature and since magnitudes and luminosities both describe the brightness of an object.

On the last page of your answer sheet, plot the *B-V* and *V* values recorded for each of the 24 stars you have measured. Be sure to take note of which star is which by labeling them (ex: *#1, #2,* etc.) as you plot them.

Once you are finished, you should be able to see the *Main Sequence* line on your graph. It's alright if some of the stars do not lie directly on the line.

We are now going to calculate the distance to the Pleiades using the *Distance Modulus Equation* and a set of *Calibration Stars*. The Calibration Stars are plotted on a plastic overlay that was given to you at the start of class. If you don't have one ask your TA for help.

Recall from class the definitions for *Apparent* and *Absolute Magnitude*. The Apparent Magnitude is how bright a star appears to be from Earth; this is what we plotted on the Color-Magnitude diagram for the Pleiades. A star's Absolute Magnitude is the magnitude the star would have if it were at a distance of 10 parsecs; this is what is plotted on the plastic overlay for a set of standard stars.

The difference between a star's apparent and absolute magnitude, or the *Distance Modulus*, gives us the distance to that star in parsecs by using the following equation:

$$(1) \qquad\qquad\qquad d = 10 * 10^{(V - M_V)/5}$$

Note that on the overlay, *Absolute Magnitude* or M_V is plotted on the y-axis, whereas *Apparent Magnitude* or V is plotted on the y-axis of the Color-Magnitude Diagram which you made. In order to determine the distance to the cluster, you will be measuring $V\text{-}M_V$ from these two graphs.

Place the overlay on top of your plot such that the two y-axes are aligned on top of one another. The x-axes will not be aligned during this part of the lab. Slide the overlay until the two Main Sequence lines are aligned as well (See Figure 9). They may not align near the top-left and bottom-right portions of the Main Sequence, but it is only important that the middle portion of the lines match up.
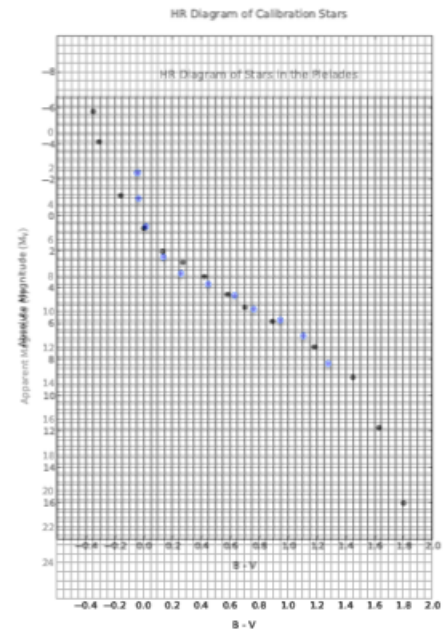

FIGURE 9

Looking at your graph and the overlay, once they are aligned, pick a number on the y-axis of the plastic overlay. This is your Absolute Magnitude or M_V value.

Next, look at the value of V on your graph that lies directly underneath the M_V number that you just chose. This is the number that you will use for the Apparent Magnitude or V value.

Calculate the Distance Modulus or V-M_V using these two values and record your answer in *Part V: Calculating a Distance to the Pleiades*.

Plug these numbers into the Distance Modulus Equation (*eqn. 1*) and record the value in *Part V* of your answer sheet. Be sure to show your calculations!

Equation 1 gives the the distance to this cluster in units of parsecs. Convert your answer to lightyears. Recall there are 3.26 lightyears in a parsec. Therefore, if your distance in parsecs was 2.0, then your distance in lightyears would be $2.0 * 3.26 = 6.52$. Record the value you calculate onto your answer sheet. Show your work!

The actual distance to the Pleiades is 410 lightyears. How does your answer compare? You can determine how accurate your answer is by using the formula for percent error provided on your answer sheet. Notice the absolute value lines in the equation. Show your work!

Congratulations! You have succesfully determined the distance to the Pleiades using photometric observations, in the B and V filters, of the stars located within that cluster.