Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Astronomy 102 Lab: Distance to the Pleiades**

Please bring your textbook to class. Use a pencil when plotting the points on the graphs.

**Pre-Lab Assignment:** From the planetarium, you know the Pleiades is a little group in the constellation Taurus of about seven stars, hence it is often called the "Seven Sisters." However, the full Pleiades cluster contains hundreds of stars and is what is known as an open cluster. In this lab, you will make an H-R diagram for part of the Pleiades cluster and use it to find the distance to the cluster. Answer these questions before coming to lab.

***A) What is an "H-R diagram?" What is its purpose?***

***B) In a sentence, describe a star that would sit in the upper right hand corner of the H-R diagram. What would it look like? Do the same for a star in the lower left hand section of the diagram.***

In the lab, you will be calculating the distance, d, in parsecs to the Pleiades using the apparent and absolute visual magnitudes of the stars, $m\_{V}$ and $M\_{V}$ respectively. Please use the table you used in the last lab, which can be found here. http://natsci.parkland.edu/ast/102/labs/stardistance.html

After calculating the distance modulus by subtracting the two magnitudes, $m\_{V}-M\_{V}$, read the corresponding distance value from the table. ***Remember,*** $m\_{V}-M\_{V} \ne d$***.***

You can use the following equation if you know how to use logarithms.

$$log\_{10}d=\left[\left(m\_{V}-M\_{V}\right)+5\right]/ 5$$

***C) Let's say that*** $m\_{V}$ ***is +2 and*** $M\_{V}$ ***is -3. What is the distance to the star in parsecs?***

***D) Let's say that the distance to another star is 350 parsecs. If the apparent magnitude is 10, what is the absolute magnitude?***

**Introduction**: An open star cluster consists of a few hundred stars of common age and origin, loosely held together by mutual gravitation and moving together through space. They are usually located in the main disk of the galaxy, in or near the spiral arms. The distance to one such cluster, the Pleiades, can be found by first plotting a color-magnitude diagram for the cluster, and then fitting the data from this graph to a standard H-R diagram, where the absolute magnitudes are plotted.

**Basic Data**: Table #1 lists two properties for many of the stars in the Pleiades cluster. The "Eggen Number" refers to a system for identifying the stars, mpg is the blue or "photographic magnitude," and mv is the "visual magnitude." The color index is the blue magnitude minus the visual magnitude, or ($m\_{pg}-m\_{V}$), which works in the same way as spectral type in determining the surface temperature (and the color) of a star. This information is like that obtained by Hertzsprung and Russell for stars near the Sun. There are no units on magnitude.

If you recall from the spectra section of class, a star's color tells you the temperature of the star. However, the color we see is a mixture of many colors. This method of using blue magnitudes and red magnitudes is a way of determining what color the star will appear to the naked eye. Remember that magnitudes are arranged such that a low number denotes a bright object. If the blue magnitude is small and the red magnitude is large, that means that the object is bright in blue and dim in red; it will appear bluish to the naked eye. Similarly, a star with a high blue magnitude and low red magnitude will appear reddish to the naked eye. Thus, in the color-magnitude and main sequence plots, the bottom axis is arranged in the same way you are used to seeing for the H-R diagram; hot stars will be on the left and cool stars will be on the right.

Table #2 lists the color index (B – V or blue magnitude minus visual magnitude) and absolute magnitude ($M\_{V}$) for a representative set of stars on the main sequence. We will compare this whole set to the Pleiades stars, but each row does not correspond to the Eggen numbers listed in the Pleiades set.

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| **Table 1: Colors and Magnitudes for the Pleiades** | **Table 2: Standard Main Sequence** |
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| --- | --- | --- |
| Eggen Number | $$m\_{pg}-m\_{V}$$ | $$m\_{V}$$ |
| 3 | 0.085 | 8.24 |
| 5 | 0.043 | 8.06 |
| 7 | 0.332 | 9.60 |
| 8 | 0.118 | 8.14 |
| 9 | 0.414 | 9.83 |
| 11 | -0.297 | 3.70 |
| 13 | 0.512 | 10.37 |
| 15 | 0.197 | 8.56 |
| 17 | -0.289 | 4.29 |
| 18 | 0.307 | 8.97 |

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| Eggen Number | $$m\_{pg}-m\_{V}$$ | $$m\_{V}$$ |
| 20 | 0.211 | 8.58 |
| 21 | 0.487 | 10.11 |
| 24 | 0.369 | 9.42 |
| 28 | -0.197 | 6.41 |
| 33 | -0.073 | 7.34 |
| 34 | 0.209 | 8.09 |
| 40 | -0.148 | 6.81 |
| 41 | 0.149 | 8.37 |
| 43 | -0.140 | 6.98 |
| 46 | -0.001 | 7.75 |

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| # | B – V | $$M\_{V}$$ |
| 1 | -0.25 | -2.10 |
| 2 | -0.20 | -1.10 |
| 3 | -0.15 | -0.30 |
| 4 | -0.10 | 0.50 |
| 5 | -0.05 | 1.10 |
| 6 | 0.00 | 1.50 |
| 7 | 0.05 | 1.74 |
| 8 | 0.10 | 2.00 |
| 9 | 0.20 | 2.45 |
| 10 | 0.30 | 2.95 |

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| # | B – V | $$M\_{V}$$ |
| 11 | 0.40 | 3.56 |
| 12 | 0.50 | 4.23 |
| 13 | 0.60 | 4.79 |
| 14 | 0.70 | 5.38 |
| 15 | 0.80 | 5.88 |
| 16 | 0.90 | 6.32 |
| 17 | 1.00 | 6.78 |
| 18 | 1.10 | 7.20 |
| 19 | 1.20 | 7.66 |
| 20 | 1.30 | 8.11 |

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**Reduction**: Plot **(in pencil)** a color-magnitude diagram for the Pleiades using the data in table #1. *Label each of the points with the Eggen number.* Note that magnitudes increase going **down** on the graph. Be careful to watch the signs of the color index values and consider that 0.015 is less than 0.1. You may prefer to round the color index values to the nearest 0.01 before plotting them, e.g. -0.129 rounds to -0.13. If you plotted correctly, your points should appear to make a smooth curve.

***1. (four answers) Based on the stars' positions in your color-magnitude diagram, which star (use its Eggen number) is the hottest? Which star is the coolest? Which is the brightest? Which is the dimmest?***

***2. If the Pleiades are all main sequence stars, which one is the most massive? How can you tell? (Hint: Check Figure 6 in Section 18.2 of the textbook that relates mass to luminosity in main sequence stars.)***

Plot **(in pencil)** an H-R diagram for the standard stars given in table #2. *Label each of the points with the number in the first column. These points should form a smoother curve than the Pleiades data. Draw a curved line through these points.*

***3. The Sun, a main sequence star, has an absolute magnitude of 4.83. Estimate its color index using the values for the Standard Main Sequence in Table 2.***

***4. Based on the color index, compare the temperature of the Sun to the stars of the Pleiades in Table 1.***

***5. Estimate the visual magnitude for a Sun-like star if it were in the Pleiades by plotting it on the graph. Circle the point and label it “S”.***

***6. Estimate the color index and the visual magnitude for a red giant that would be in the Pleiades by plotting it on the graph. Circle the point and label it “RG”. Explain your reasoning below. (Consider where a red giant would be compared to main sequence stars.)***

***7. Estimate the color index and the visual magnitude for a white dwarf that would be in the Pleiades by plotting it on the graph. Circle the point and label it “WD”. Explain your reasoning below. (Consider where a white dwarf would be compared to main sequence stars.)***

Place the color-magnitude diagram of the Pleiades over the standard main sequence on the light table and align the color index scales at the bottom. Keeping these scales aligned, slide the top graph up or down until the color-magnitude data points best overlay the standard main sequence curve.

Each value of $m\_{V}$ on one graph has a corresponding value of $M\_{V}$ on the other graph. The difference between those values, $m\_{V}-M\_{V}$, will be the same throughout the H-R diagram. The easiest way to determine $m\_{V}-M\_{V}$ is to find $M\_{V}=0$ on the axis. Then determine what value of $m\_{V}$ is above that point. Since $m\_{V}-0=m\_{V}$, the value of $m\_{V}-M\_{V}$ will give you the distance modulus.

***7.*** $m\_{V}-M\_{V}$ ***=***

Use the m – M vs. distance chart you used in the Properties of Stars lab to determine the distance in both parsecs and light-years. Remember that one parsec corresponds to 3.26 light-years.

http://natsci.parkland.edu/ast/102/labs/stardistance.html

***8. Distance to the Pleiades (in parsecs):***

***9. Distance to the Pleiades (in light-years):***

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| **Calculating percent errors:** Percent errors are calculated using the following equation: $$\% error=(accepted value – measured value) / accepted value ×100$$For example, let's say that a quantity has an accepted value or 280 and a measured value of 320. The percent error would be: 1. 280 – 320 = -402. -40 ÷ 320 = -0.1253. 0.125 × 100 = -12.5%. Negative errors are fine. |

The accepted value for the distance to the Pleiades is 135 parsecs. Calculate a percent error for your distance determination.

***10. Percent error for Pleiades distance:***

***11. What could be done to decrease the error in the method?***

The brightest star in the Pleiades cluster is Alcyone (“Al-sai-uh-nee”), with $m\_{V}=2.86$ and a B7 spectral class. Use the tables you used in the last lab to answer the following questions. **Don't use information you can find online to get these answers because the data provided will yield different results.**

http://natsci.parkland.edu/ast/102/labs/properties\_known\_spectra.jpg

http://natsci.parkland.edu/ast/102/labs/stardistance.html

http://natsci.parkland.edu/ast/102/labs/MagLum.html

***12. Estimate the temperature of Alcyone.***

***13. Given the distance you calculated for the Pleiades, what is Alcyone's absolute magnitude? (Hint: check what you did in the pre-lab.)***

***14. Estimate the luminosity of Alcyone, in terms of the Sun.***

**Extra credit:** There is an expression that relates luminosity and temperature to the size of the star.

$$L=4πR^{2}σT^{4}$$

In the equation, L is luminosity, R is the star's radius in centimeters, T is the star's temperature in Kelvin, and σ is a constant that's equal to 5.67 × 10-5. The number you wrote for the luminosity of Alcyone is in terms of the luminosity of the Sun. Multiply that value by 4 × 1033 to get the luminosity of Alcyone in the proper units.

What is Alcyone's radius in centimeters? Show your work on scratch paper, which can be provided upon request. I recommend algebraically solving for R before doing any calculations.

The Sun's radius is 70,000,000,000 cm or 7 × 1010 cm. How does this compare to the radius of Alcyone? Calculate the ratio of the sizes of the stars by dividing Alcyone's radius by the Sun's radius.



