PHY-255 Name: _____

Determining the Relative Ages of Two Open Clusters:

Background:

Open Cluster:

An open cluster is a family of stars that were born from the same cloud of gas and dust, and can contain upwards of thousands of stars. Because the stars in an open cluster were all born at the same time, astronomers can examine the types of stars in the cluster to determine its age. Because stars of all types are born in an open cluster, the presence of short-lived main sequence stars like O, B, A, and F stars indicate that a cluster is young, while the absence of these stars indicates that a cluster is old enough that the O, B, A, and F stars have died in the intervening time since the cluster was formed.

M67:

M67 is an open cluster of stars around 2800 light years away from us.[1]

NGC188:

NGC188 is an open cluster of stars around 5400 light years away from us.[2]

Goal:

Our goal today is to determine which star cluster is older.

Skills:

Here are the skills we are developing today:

- Color Magnitude Diagrams (CMDs)
  - How to create CMDs – A Color magnitude Diagram plots the color index of a star on the horizontal axis and the absolute magnitude on the vertical axis. If we invert the vertical axis, the main sequence runs from the top left to the bottom right of the diagram.
  - How to interpret CMDs – Short-lived stars are in the top left of the diagram while longer-lived stars are in the bottom right region of the graph. So if a star cluster still has short-lived stars, it must be young. We can compare the relative ages of two different star clusters by seeing which one "turns off" of the main sequence further down the main sequence.

1 - Top image (M67) credit: https://en.wikipedia.org/wiki/Messier_67#/media/File:M67_Mazur.jpg
2 - Bottom image (NGC188) credit: https://en.wikipedia.org/wiki/NGC_188#/media/File:C1_=_NGC_188.jpg

- Python
  - Using the pandas library to read in data from a file in Kaggle (see python template)

  - Calculating new columns in python with the pandas library:

```
# We need to calculate the distance to each star from its parallax.
# The syntax below allows you to create a new column in your data frame:
data_M67['distance'] = 1/data_M67.parallax
# In this case, we create a distance column
```

  - Creating data visualizations in python:

```
x = [0, 1, 2, 3, 4, 5, 6, 10]
y = [1, 4, 7, 10, 13, 16, 19, 31]

plt.plot(x, y, 'b.') #This command plots x vs. y and plots them as blue dots ('b.')
plt.show() #This command shows the plot
```

Problems:

1. First, make a "fork" (a copy) of the Kaggle notebook template here: https://www.kaggle.com/code/austinhinkel/twoclustercmd-template/notebook – Click the three dots at the top right and select copy and edit notebook.

2. Now let's read in the files that contain the data we'd like to analyze. You can find the 'path' to your file in the right-hand side of the Kaggle notebook environment. Read in "NGC188_filtered.csv" into your Kaggle notebook and name the variable "data_NGC188". Follow the prompts in the template notebook to explore the data.

3. The Gaia Space Telescope measures the parallax angle for each star in milli-arcseconds (mas). To find the distance to a star in units of kiloparsecs (kpc), we can use the following equation:

$$distance(kpc) = \frac{1}{parallax(mas)}$$

   Calculate a new column named distance for each star cluster using the above equation. Verify the first entry in the data by doing the calculation with pen and paper here:

4. Gaia also measures the apparent magnitude of each star, which is named "phot_g_mean_mag" in our data. In order to calculate the absolute magnitude, one can use the following equation:

$$Absolute\ Mag = Apparent\ Mag - 5 \cdot \log_{10}\left(\frac{d}{0.01\ kpc}\right)$$

Complete the code in the Kaggle notebook template. Verify the number you get for the absolute magnitude of

5. Finally, complete the plotting code in the template notebook. Interpret your results and state which open cluster must be older. Explain your choice in at least a few sentences.

Your instructor will check your Kaggle notebook and will sign off here when it is complete:

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