Color-Magnitude Diagrams for Two Star Clusters:

Background:

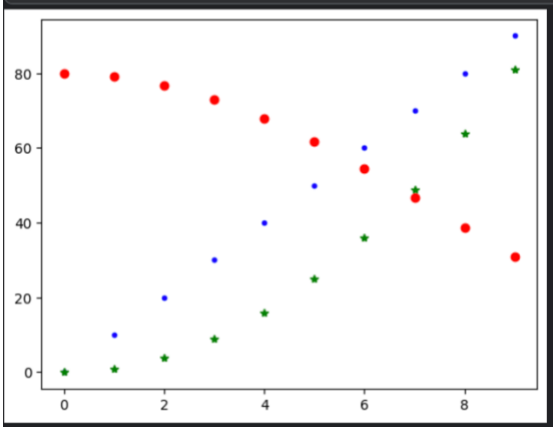
A Color-Magnitude Diagram (CMD) is the observational equivalent of an HR diagram. It plots the absolute G-band magnitude on an inverted vertical axis and the blue-pass minus red-pass color on the horizontal axis. We will produce CMDs for two open clusters: NGC188 and M67. We'll use the CMDs to figure out which cluster is older.

Skills:

Here are a few things that may be helpful:

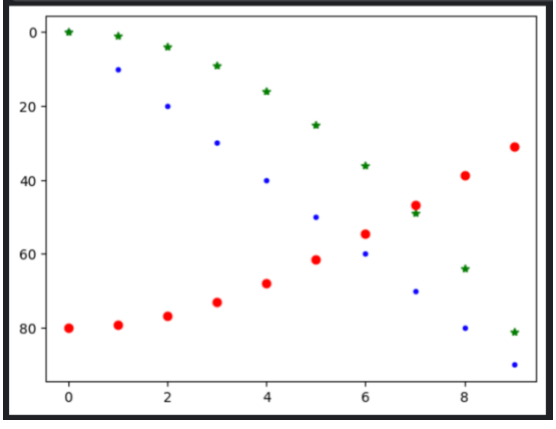
- Change marker color and style in a plot (k=black, r=red, b=blue, g=green, etc.):

```
plt.plot(x, y1, 'b.')
plt.plot(x, y2, 'g*')
plt.plot(x, y3, 'ro')
plt.show()
```



- Invert an axis:

```
plt.plot(x, y1, 'b.')
plt.plot(x, y2, 'g*')
plt.plot(x, y3, 'ro')
plt.gca().invert_yaxis()
plt.show()
```



Problems:

Part I:

We will make two separate queries for this part, one for each star cluster we will be studying. In both cases, we need to query the following columns:

- Parallax
- G-band magnitude
- bp-rp color
- Proper motion in the RA direction
- Proper motion in the Dec direction

Additionally, we will need to make the following conditions in both queries:

- BP minus RP color cannot be null
- parallax > 0 (Removes bad measurements)
- parallax_over_error > 4 (This is the same as demanding that the relative parallax error be less than 25%)

For Query 1, we will be obtaining data for M67, an open cluster. For this cluster, ask for stars with $215 < l < 216$ degrees and $31.5 < b < 32.5$ degrees.

For Query 2, we will be obtaining data for NGC188, an open cluster. For this cluster, ask for stars with $122 < l < 123.5$ degrees and $21.5 < b < 23$ degrees.

Part II:

Upload these files into Kaggle so that you can write a python program to analyze them.

For each cluster, plot the proper motion in the RA direction vs. proper motion in the Dec direction. These clusters are approximately gravitationally bound, and thus move together through space. Determine cuts to make on each component of the proper motion in order to keep only stars which belong to the cluster, ignoring the surrounding field stars. (Hint: you will likely have to replot the data a couple of times to zoom in on the region of the plot you are interested in. Note: plt.xlim([xmin, xmax]) and plt.ylim([ymin, ymax]) are useful here).

Part III:

After you have developed a satisfactory series of cuts, plot the CMD for each cluster on the same plot, using a different color for each. What do you notice? How are they different? How are they the same? Based on the plots you have generated and what you've learned in class, which cluster do you suspect is older? Can you find the ages of each cluster on the internet? Do your results agree? (Hint: you can recycle some of your old code)