ASTR 222 – Galaxies & Cosmology

Homework 1 – Due 7 February 2024, 2pm
100 points

Star Counts

In star count lingo, $N(m)$ is defined to be the number of stars observed with apparent magnitude *brighter* than m. As we saw in class, if the Galaxy had a uniform density of stars and is infinite in extent, we should see the star counts go as $\log N(m) \sim 0.6m$ (even if stars don't all have the same brightness).

Here is a table of integrated star counts (`http://astroweb.case.edu/bjanesh/astr222/NmAPQ3.dat`) expressed in $\log N(m)$ (again, $N(m) =$ number of stars brighter than apparent magnitude m) from Allen's "Astrophysical Quantities." The columns are:

- `mag`: apparent magnitude (m)

- `logN_up`: $\log N(m)$ in a direction up out of the galactic plane

- `logN_in`: $\log N(m)$ in a direction towards the galactic center

With this data, make a single plot showing $\log N$ vs m in the two different directions. Also include on the plot the expected $\log N$-vs-m relation for an infinite, uniform distribution of stars ($\sim 0.6m$). Explain qualitatively why the star counts in different directions are different from each other, and also why they are different from the uniform model.

Note: $\log N$ *goes on the y-axis and* m *goes on the x-axis.*

Fun with Magnitudes!

a. A (very strange!) star cluster is made up of 10^6 stars identical to the Sun ($M_V = +4.83$, $B - V = 0.65$). What is its total V-band absolute magnitude? What is its $B - V$ color?

b. Another very strange star cluster is made up of 10^6 Suns and another 10^5 red giants ($M_V = +1.00$, $B - V = 1.0$). What is its total V band absolute magnitude? What is its $B - V$ color? What fraction of the total V band light of the cluster is coming from the red giants?

Tip: the absolute magnitude of the Sun in B is $M_B = +5.48$ *and in V is* $M_V = +4.83$. *How would you compute the individual luminosity in B and V of a star above using those values?*

HR Diagrams

Based on what you know about stellar evolution, stellar populations, and the colors and magnitudes of stars, sketch what you might expect an HR diagram for the solar neighborhood to look like. Tip: think about what kinds and ages of stars might be present (and most common!) in the solar neighborhood.

Remember that HR diagrams are theoretical distributions of where stars fall in color and magnitude. Color-magnitude diagrams (CMDs) are what we actually observe. Write down potential biases in observing stars in the solar neighborhood. Based on these biases, sketch what you think the solar neighborhood CMD will look like. Describe the major differences.

Galactic Coordinates

a. Estimate the height (z) above or below the Galactic plane for both M13 ($\ell = 59.0°$, $b = 40.9°$) and the Orion Nebula ($\ell = 209.1°$, $b = -19.4°$). M13 and the Orion Nebula are 7 kpc and 450 pc from Earth, respectively.

b. To which components of the Galaxy do these objects likely belong? Explain your answers.

Studying the Galaxy with Globular Clusters

Here is a list of (real!) data for globular clusters.
`http://astroweb.case.edu/bjanesh/astr222/gc.dat`
The data give:

- the angular coordinates of each cluster in galactic coordinates (ℓ, b).

- the distance from the Sun, R, in kiloparsecs

- the metallicity of the globular cluster, [Fe/H]. (Note: if [Fe/H] = 999, that means there is no measurement.)

- the observed radial velocity of the cluster, V_r, in km/s. (Note: if $V_r = 999$, that means there is no measurement.)

We are going to use this data to learn about the distance to the galactic center, and the rotation speed of the Milky Way.

First, transform the observed data (ℓ, b, R) into cartesian coordinates (X, Y, Z). $+X$ should point towards the galactic center ($\ell = 0$), $+Y$ should point in the direction of rotation ($\ell = 90$), and $+Z$ should point above the plane (positive b).

Defined this way, we have:

$$X = R \cos \ell \cos b$$
$$Y = R \sin \ell \cos b$$
$$Z = R \sin b$$

a. Calculate and plot the X, Y, Z positions to get a feel for the distribution of globular clusters in the Galaxy. Plot the X, Y and X, Z projections so that you can see how things are distributed along each axis.

b. Make X, Y and X, Z plots for the metal-poor globular clusters with $[\text{Fe/H}] < -0.8$

c. Make the same plot for the metal-rich globular clusters with $[\text{Fe/H}] > -0.8$

   Note: Be careful not to include clusters which do not have measured [Fe/H]! So make sure to "filter" your data. Try something like this:

   ```
   # define which clusters are metal rich
   MR = (feh > -0.8) & (feh != 999)
   # only plot metal rich clusters
   plt.scatter(x[MR],y[MR])
   ```

d. Explain how the two distributions are different.

   Coding alert: Make sure your plots have the same XYZ range, and that a circle would be a circle on your plot! Otherwise you won't be able to compare the shape and extent of the two distributions. Two tips for making this plot:

   - *Set the x and y limits on your plot by hand, rather than letting python autoscale the plot.*
   - *Tell python you want equal axis ratio on your plots. Say* `plt.axis('equal')`, *or if you are using subplots, say* `subplot_name.set_aspect('equal')`.

e. In the 1910s, Harlow Shapley[1] derived the distance to the Galactic Center by using the positions of the globular clusters. Now it's your turn:

   - What is the (X, Y, Z) center of the metal-poor globular cluster system? How far, then, is the Galactic Center?
   - What is the (X, Y, Z) center of the metal-rich globular cluster system? How far, then, is the Galactic Center?
   - Which of these two measurements do you feel is more accurate? Why?

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[1] `https://en.wikipedia.org/wiki/Harlow_Shapley`