Semester 2 2024

Astroinformatics II

Graded Practice 1

- Content: Application of what has been learned in class.
- Finished code, plots (if applicable to the tasks) and a short report in English summarizing your work is to be submitted within one week to this e-mail address: `nina.hernitschek@uantof.cl`
- Using information from to the internet is allowed. Cite everything properly.
- Working together/ sharing solutions among students is not allowed.

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1 Introduction

This project, consisting of four practices, is around the topic of globular clusters.
Globular clusters are useful astronomical objects to study the past of our galaxy:
The globular clusters surrounding a galaxy provide a fossil record of the dynamical and chemical conditions when the galaxy was in the process of formation. Looking at globular clusters in our Milky Way and in other galaxies, we can track their orbits to find signs of past collisions, which helps trace the history of galaxy evolution. As globular clusters are rich of variable stars (such as RR Lyrae), we can also determine their distance and age well.

2 Tasks

All code is to be written in Python.
You can search the internet and reuse code (because it is realistic to do so). Always test, properly cite and document reused code.
Submit your solution via e-mail: code files, plots, and everything put together into a text document (LaTeX) where you also describe what you did and possible problems (and solutions) you discovered.

2.1 Task 1: Access data

Get the file `gc.dat` from the github repository.
This file contains:

- columns `l` and `b`: The angular coordinates of each cluster in galactic coordinates (l, b). These coordinates are the observed angular position of the globular cluster, as viewed from the Sun (i.e., our viewing position). If for example a cluster has coordinate $(0°, 20°)$, it would be viewed 20 degrees above the Galactic disk plane, in the direction of the Galactic center.
- column `R`: the distance from the Sun, measured in kiloparsecs
- column `feh`: the metallicity of the globular cluster, [Fe/H]. (Note: if `feh` is `999`, that means there is no measurement.)
- column `vr`: the observed radial velocity of the cluster, V_r, in km/s. (Note: if `vr` is 999, that means there is no measurement.)

First, use Python to make a plot that shows the position of the globular clusters on the sky and explain why you decided for the plot type you had chosen.

2.2 Task 2: Filter data

Transform the observed data (l, b, R) into cartesian coordinates (X, Y, Z). $+X$ should point towards the galactic center ($l = 0°$), $+Y$ should point in the direction of Galactic rotation ($l = 90°$), and $+Z$ should point above the plane (positive b). Defined this way, we have

$$X = R\cos(l)\cos(b)$$
$$Y = R\sin(l)\cos(b)$$
$$Z = R\sin(b)$$

Hint: Often trigonometric functions assume angles are given in radians, not degrees. The file lists angles in degrees. So for this reason, you must convert. Example: `Z=R*np.sin(b)` would be incorrect, but `Z=R*np.sin(np.radians(b))` will work.

a) Calculate the X,Y,Z positions and write them to a table.
Plot the X-Y and X-Z projections so that you get an idea of the distribution of globular clusters in the Galaxy.

b) Then extend this by filtering data:

- Make $X - Y$ and $X - Z$ plots for the metal-poor globular clusters with $[Fe/H] < -0.8$
- Make the same plot for the metal-rich globular clusters with $[Fe/H] > -0.8$

Hint: Be careful not to include clusters which do not have measured $[Fe/H]$. Try something like this:

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

c) Explain how the two distributions are different.
Hint: Make sure your plots have the same XYZ range. Otherwise you won't be able to compare the shape and extent of the two distributions. You can get this by:

- Set your own limits on the plots, instead of letting Python autoscale the plot.
- Use equal axis ratio on your plots by using `plt.axis('equal')`, or if you are using subplots, `subplot.set_aspect('equal')`.

2.3 Task 3: Plot more information

Finally, we can use the observed velocities of the globular clusters to get the rotation speed of the Galaxy.
For this, plot V_r (on the y-axis) against l (on the x-axis). Only use the metal-poor globular clusters (as selected in b)) for this exercise.
In the plot, you should see a lot of dispersion, but a slightly sinusoidal trend. At $l = 90°$ the radial velocities are more negative, at $l = 270°$ they are more positive. The reason for this is that the globular cluster system isn't rotating. Remember that $l = 90°$ points along the direction of rotation; clusters along $l = 90°$ are in front of us and we are moving towards them, so they have a negative (approaching) radial velocity (and vice versa for the clusters at $l = 270°$).
Hint: Make sure not to include clusters which have no measured Vr in your analysis! Use the filtering technique we talked about above.

2.4 Task 4: Code optimization

With your code written so far, try to find parts of the code that could be speed up with the techniques learned in lecture 2 and 3. Measure code execution time. You might change your code to the usage of more *Pythonic* code such as generators. Describe which part can be speed up, and try to implementing it and again measure the code execution time.