Homework 3

Chemical Cartography

This week we're going to recreate a few famous plots, to explore a few of the intricacies of "Galactic Chemical Cartography". The suggested data source is the APOGEE allStarLite catalog. It might be possible to recreate all of these findings from other data sources (e.g. GALAH, RAVE, Gaia itself, etc), but I haven't tried them!

This archive of stellar abundances is an extremely rich data source, and new populations/structures are actively being discovered… **You could find something neat in here!**

Part 1

(25pts)

1.1. Get your data.

Download the (large) .fits file from the SDSS website. *Note: this server is a bit slow, it may be faster to use a thumb drive from one of your colleagues.*

Read the file into your notebook (I like Astropy Tables for this). How many rows are there (each row is 1 star)? How many columns? (SO MANY! Be sure to look at the Datamodel page). It's an incredible file… marvel at how much information is condensed here!

1.2. Make a "Wallerstein–Tinsley Diagram", $[\alpha/M]$ versus $[Fe/H]$

You'll need to select only stars with finite $[\alpha/M]$ and $[Fe/H]$ measurements (i.e. no NaN's). Probably best to create a 2-D histogram plot. Play with color scales or log-scaling the color map to make the best-looking figure.

What features or stellar populations can you identify here? (i.e. Thick/Thin disks)

It can be helpful to define a polygon or region to separate the high- vs low-α populations (e.g. Figure 1 here).

1.3. Make new versions of this diagram for Dwarfs and Giant stars

Select based on something like: $\log g \geq 3.5$ for dwarfs, < 3.5 for giants.
N.B. this is a VERY rough evolution cut…

The APOGEE sample is dominated by giants because they probe much further reaches of the Galaxy. **Which galactic disk(s) can you see for each of these two stellar populations?**

Part 2
(25)

2.1. Convert the observed (RA, Dec, dist) into galactocentric (XYZ)
Probably best to use Astropy for this. For distance, I would suggest using the column:
`GAIAEDR3_R_MED_GEO`

Plot the vertical (Z) distribution of stars chemically identified in Q1.2 as Thick vs Thin.
Do Dwarfs or Giants trace each disk better? Helpful to normalize your histograms here.

Can you estimate the scale-height for these populations? You could fit a Gaussian to the log number of stars as a function of height.
N.B. this will be a bad estimate, since there are many sample biases we are not accounting for!

2.2. Plot the mean metallicity $[Fe/H]$ of stars in the (R, Z) plane
What trend(s) do you notice?

What does the same plot colored by mean $[\alpha/M]$ look like?

Part 3
(25)

3.1. Can you find stars that the Milky Way has accreted?
(e.g. Gaia-Enceladus/Sausage stars?)

You can either try recreating [Mg/Mn] versus [Al/Fe] plot in Figure 1 here (my recommendation!) or get very fancy exploring the energy versus momentum plane in Figure 1 here.

3.2. Where is it?
Where do these accreted stars land on the Wallerstein-Tinsley diagram?
Where do they land on the (R,Z) plane?

3.3. Anything else neat you can find in the ASPCAP/AllStars file?
Any clusters? Halo stars? The "Jurassic" structure? The "Sequoia"?

Turn In
Use this Dropbox Link to turn in a PDF of your write-up.

This could simply be a saved Jupyter notebook with lots of annotation/discussion, or could be formatted in LaTeX with embedded figures. Remember to **show your work**, meaning the provenance of your data and the decisions you've made to create your figures.

Collaboration is encouraged for problem solving. Please list clearly all your collaborators! Each person is responsible for turning in an obviously unique work product (i.e. you write your own code, your own discussion, etc). This is a graduate course: I don't care about you getting the *right* answer as much as I want to see the efforts of your thoughts and synthesis!

Nominal Due Date: 2023-02-17