Term Project # 3

Galactic Astronomy (Astr 511); Winter Quarter 2017
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1. Introduction

This homework is based on APOGEE-ASPCAP data[1]. We will use measured abundances for 15 elements (from summary APOGEE-ASPCAP allStar file) and other data to study the variation of abdundance distribution as a function of stellar population (halo, thin disk, thick disk).

Copying verbatim from the SDSS Data Release webpage[2], "The APOGEE Stellar Parameters and Chemical Abundances Pipeline (ASPCAP) employs a two-step process to extract abundances: first, determination of the atmospheric parameters by fitting the entire APOGEE spectrum, and second, use of these parameters to fit various small regions of the spectrum dominated by spectral features associated with a particular element in order to derive the individual element abundance." The first ASPCAP step estimates seven stellar parameters: effective temperature, surface gravity, microturbulence, overall metal abundance $[M/H]$, relative α-element abundance $[\alpha/M]$ (defined as O, Mg, Si, S, Ca, and Ti changing with solar proportions in lockstep), carbon $[C/M]$, and nitrogen $[N/M]$ abundances. The second step estimates abundances of the following 15 elements: Al, Ca, C, Fe, K, Mg, Mn, Na, Ni, N, O, Si, S, Ti, and V. The $[\alpha/Fe]$ value estimated during the first ASPCAP step and a corresponding value based on the measured abundances of individual α elements (note that α elements Ne and Ar are missing):

$$[\alpha/Fe]^* = \frac{[O/H] + [Mg/H] + [Si/H] + [S/H] + [Ca/H] + [Ti/H]}{6} - [Fe/H], \quad (1)$$

are in good agreement. In other words, $[\alpha/Fe]$ shows good correspondence to the *mean* value of the abundances of the above six elements, and the last term transforms the scale from "per H" to "per Fe".

These stellar parameters and abundances (for 163,278 stars) are conveniently stored in

a single fits[3] file; the Data Release 12 version[4] is named allStar-v603.fits. If the data are read as

```
data = pyfits.open('allStar-v603.fits')[1].data[::1]
```

then $[\alpha/Fe]$ from the first stage can be accessed as

```
alphaFe = data['PARAM_ALPHA_M']
```

while individual abundances can be accessed as, e.g. for Mg and Ti,

```
MgH = data['MG_H']
TiH = data['TI_H'].
```

The overall metal abundance can be read as

```
MH = data['PARAM_M_H']
```

and $[Fe/H]$,

```
FeH = data['Fe_H'].
```

Using these data (for extra credit, use quality flags[5] too!) and

1. Estimate the median difference and root-mean-square (rms) scatter of the difference between $[\alpha/Fe]$ and $[\alpha/Fe]^*$. Does the distribution of this difference appear Gaussian? Is the median difference correlated with T_{eff}, log(g), $[Fe/H]$, or $[\alpha/Fe]$?

2. Estimate the median difference and root-mean-square (rms) scatter of the difference between $[M/H]$ and $[Fe/H]$. Does the distribution of this difference appear Gaussian? Is the median difference correlated with T_{eff}, log(g), $[Fe/H]$, or $[\alpha/Fe]$?

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[3]For data model, see https://data.sdss.org/datamodel/files/APOGEE_REDUX/ APRED_VERS/APSTAR_VERS/ASPCAP_VERS/RESULTS_VERS/allStar.html

[4]For download, see http://www.sdss.org/dr12/data_access/bulk/

[5]See ASPCAP Bitmasks at http://www.sdss.org/dr12/irspec/parameters/

3. Plot the K vs. J−K color-magnitude Hess (pixelized) diagram and color code it by the mean $\log(g)$ per pixel. Do you any structure in the $\log(g)$ distribution (that is, is $\log(g)$ correlated with J-K or K)? If so, discuss and explain it. Note that this real data file also includes some outliers; the plausible ranges to be used in the plot are 0.0 to 4.0 for J-K color and 14 to 6 for K magnitude (real astronomers plot magnitudes as decreasing along y axis (bright is up)!).

4. Plot $\log(g)$ vs. T_{eff} Hess diagram and color code it by the mean $[Fe/H]$ per pixel. Describe and explain the seen structure (hint: the gradient of $[Fe/H]$). Axes should be oriented so that this diagram resembles a standard Hertzsprung-Russell diagram.

5. Plot $[\alpha/Fe]$ vs. $[Fe/H]$ Hess diagram and color code it by the mean $[Fe/H]$ per pixel. Overplot contours showing the number of stars per pixel. Do you any structure? If so, discuss and explain it. Hint: plot $[\alpha/Fe]$ histogram for a subsample with $-0.5 < [Fe/H] < -0.2$; is it Gaussian?

6. Plot $[\alpha/Fe]$ vs. $[Fe/H]$ Hess diagram and color code it by the velocity dispersion (rms scatter) per pixel. Overplot contours showing the number of stars per pixel. Do you any structure? If so, discuss and explain it.

7. Now repeat the last step separately for stars with Galactic latitudes $|b| < 5°$ and $|b| > 20°$ and discuss if your previous answer makes sense.

Hint: the halo, thick disk and thin disk populations can be approximately defined as:

```
# define thin/thick/halo subsamples using [Fe/H] and [alpha/Fe] cuts
MH = data['PARAM_M_H']
alphaFe = data['PARAM_ALPHA_M']
condHalo = (MH > -2.5) & (MH < -1.1))
condDisk = (MH > -0.9) & (MH < 0.6))
condThin = (condDisk & (alphaFe > 0.0) & (alphaFe < 0.15))
condThick = (condDisk & (alphaFe > 0.15) & (alphaFe < 0.35))
```