Spectral Analysis of Metal Poor Stars In the Halo Region

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April 1st, 2020

1 Abstract

The objective of this article is to properly format spectral data of a star for the program MOOG (Sneden). MOOG is a program commonly used in Astrophysics and Astronomy to determine elemental compositions of stars. In this article we will show how python is an ideal way of retrieving data from a fits file, and smoothing/normalizing the data for MOOG. As well, properly format the data to a text file, so MOOG is able to read it.The objective of this article is to properly format spectral data of a star for the program MOOG (Sneden). MOOG is a program commonly used in Astrophysics and Astronomy to determine elemental compositions of stars. In this article we will demonstrate how python can be used to smooth and normalize spectral data.

2 Introduction

Through Spectroscopy, the study of light at particular wavelengths and fluxes, spectral lines are observed and used to determine elemental abundances found in the light's source. From the observations of the data collected from the Hubble Space Telescope (HST). HD6268's location is in the Halo Region of the Milky Way Galaxy. The Halo Region positioned outside the plain of the Milky Way Galaxy. It has some of the oldest stars in the Milky Way. This region is vast, which allows the stars to have an extreme distance between them. Since these stars are much older, and have no previous generation of stars before them, their metallicity is lower than the typical star found in the Milky Way.

3 The Data

The Data collected from the Hubble Space Telescope is for the star HD6268. The file extracted is a fits file, which is commonly used in Astrophysics and Astronomy. Fits stands for Flexible Image Transport System, and is beneficial because it can store large amounts of data in a multi-dimensional array, as well a header and other information related to the star such as date, sensor, position in the sky, etc. For star HD6268 the interest is in the wavelengths and their corresponding flux (or intensity). The data sets are used to determine the abundances of different elements in the star. But, the data found in the fits file is raw data and must be formated.

The first step is to extract the data from the fits file. This is simply done by using functions from the Astropy module in Python (ast). Two arrays are extracted; one being the wavelength and the other being the flux. Figure 1 is what the spectrum looks like in its unaltered form.

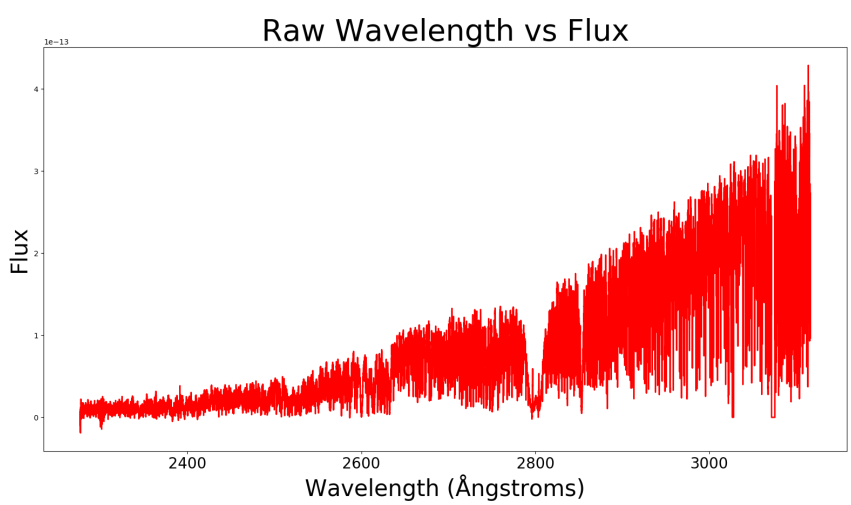

Figure 1: Raw Spectrum of HD6268

4 Smoothing

There is clearly a lot of noise that needs to be filtered out. Some causes for the noise are other nearby sensors or electronics,background radiation from other unknown cosmic sources (e.g cosmic rays), sensitivity of the sensors to certain wavelengths. To filter out the noise a method known as boxcar smoothing is applied here. The premise of boxcar smoothing is that in an array you go a certain amount of elements before and after the element that is being examined, and then average those elements to a single point. Then move to the next element in the array and repeat the process. Some data will be lost at the beginning and the end of the data set, but these data sets are so large that it should not matter. The following equation 1, from Mark Newman's textbook "Computational Physics" (Newman), is used for the smoothing process. The k value being the elemental position in the array, and the r value being how many elements you are summing before and after the current element you are at.

$$Y_k = \frac{1}{2r+1} \sum_{m=-r}^{m=+r} Y_{k+m} \tag{1}$$

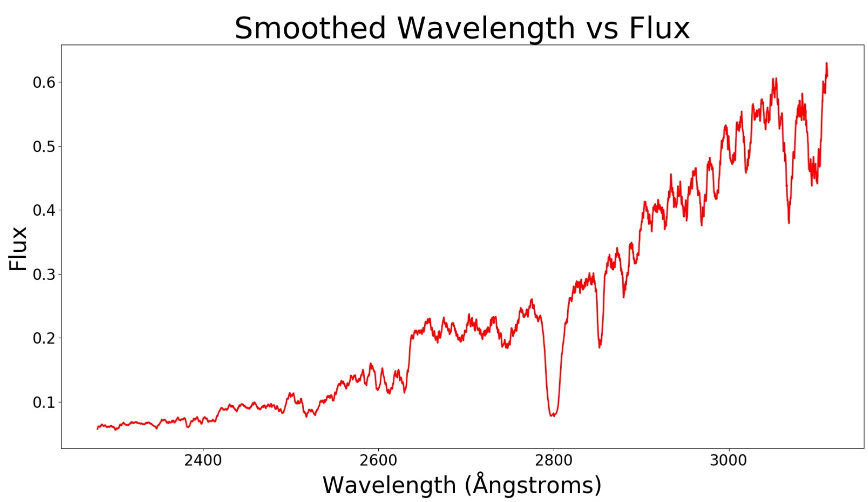

Figure 2: Smoothed Spectrum of HD6268

Figure 2 is the process after running the smoothing function with a r value of 150. Comparing to Figure 1, much of the features are easier to distinguish. It is important that an appropriate r value is chosen; if the user chooses an r value that is too high than commonly the main features of the spectrum are eliminated.

5 Normalizing

Now for MOOG (Sneden) to properly read the data, the data must be normalized between zero and one. To normalize the data we use a standard method in statistics to normalize the data. Equation 2 is used to normalize the function, with x_{max} being the maximum value in an array and x_{min} being the minimum (Stephanie).

$$X = \frac{x - x_{min}}{x_{max} - x_{min}} \tag{2}$$

Running through the normalization procedure it can be seen in figure 3 there is a range of fluxes between zero and one.

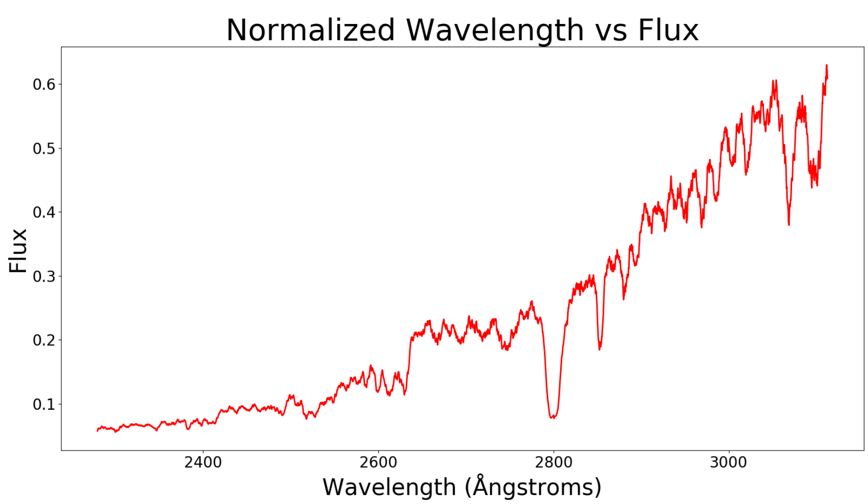

Figure 3: Normalized Spectrum of HD6268

6 Conclusion

MOOG is now able to read the formated data. Once when the data is ran through MOOG, the user can determine known abundances at certain wavelengths. From there you can make comparisons with our Sun, and other stars that we know their elemental abundances, and determine the ratio of heavy elements found in the star. As well, the data can be used to calculate the age of the star. For future work, I would like to include a Blackbody function, also known as a Planck function, and flatten the data. Flattening the data would account for varying sensitivity in the sensors used by HST (and other telescopes).

References

[ast] FITS file handling (astropy.io.fits) — astropy v4.0. https://docs.astropy.org/en/stable/io/fits/.

[Newman] Newman, M. *Computational Physics – Sample chapters*. First edition. http://www-personal.umich.edu/ mejn/cp/chapters.html.

[Sneden] Sneden, C. MOOG. https://www.as.utexas.edu/ chris/moog.html.

[Stephanie] Stephanie. Normalized data / normalization. Library Catalog: www.statisticshowto.datasciencecentral.com Section: Statistics How To.