Project 3 written

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Abstract

This project consists of several parts, a Motivation, Methodology, Results, and Conclusion. We are to analyze solar data and complete several tasks listed below. This type of analysis is done with understanding from in class lectures, examples, and light research. This project was divided equally among our group. Ian Luckeydoo is responsible for the code that analyzed out information, Blake Sodikoff is responsible for our presentation slides, and Angelo O'Dorisio is responsible for the written report

1 Motivation

When studying planetary science, it is essential to understand the host stars of the planets in question. Elemental abundance plays a crucial role in gathering information about a star's composition, which, in turn, helps infer the composition of the planets orbiting it. This not only broadens our geological knowledge of the planet, but also provides valuable insights into planetary atmospheres and gases. Such analyses can reveal factors like a planet's age and, even more interesting, its potential habitability.

For this particular analysis, we are considering a solar sodium doublet line, by taking our experiment and analyzing with respect to our own Sun, we can understand this project in a context that we can more easily understand.

Ultimately by analyzing these results

- Number density of Na atoms in all states (including ground)
- Number density of both neutral and ionized Na atoms
- Abundance in terms of both physicist and astronomer

We can pave a way to analyze other stars, ultimately comparing them to our own and through trends and tendencies, find stars similar to ours that have a possibility of supporting life on their planets

2 Methodology

This project utilizes data from our Sun, specifically *wavelength* and *flux* through 19 columns and 2 rows, the data is funneled into a series of commands that helps to break down and analyze it.

Let's start with some basic assumptions here, firstly we can imagine a vast majority of sodium atoms will remain neutral, in the suns photosphere which ultimately is what we are analyzing. Secondly we can imagine the Number density to be quite high given that it is a solar study, and high densities in general are common in objects with large gravities

2.1 Data Processing

Analyzing the date we have been given, we put the numbers into a table. As previously stated they are divided into 2 rows, the table is then analyzed and put into a graph to find doublet lines. Arbitrarily choosing values in between a doublet line, we will analyze the part of the graph between 5887.5 angstroms and 5892.5 angstroms.

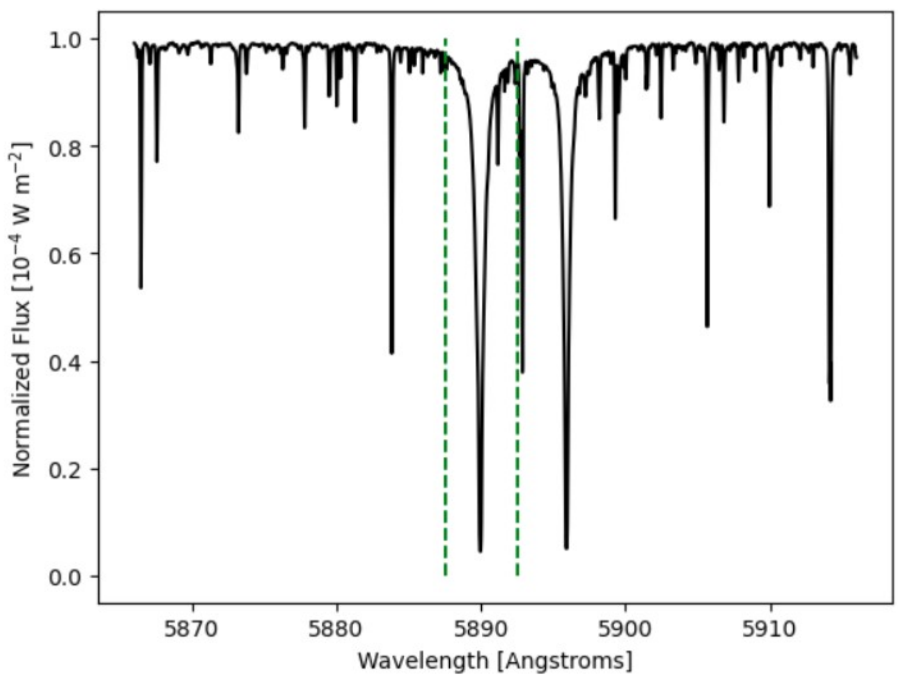

Figure 1: this figure gives a total overview of our data set before we focus in between the points described above

Lastly, before we can move onto our calculations, we gather the equivalent width and atom density from our data set using code provided in lecture.

2.2 Data Calculation

The first thing we are tasked with finding is the number density of Na atoms in the ground state and the excited state, using results from the internet we gather that degeneracy levels are *2 for stable Na* and *6 for unstable Na*, we will touch back on these later. the first thing we find is the energy for each state

$$E = \frac{h * c}{\lambda} \tag{1}$$

incorporating this into the Ratio

$$R = \frac{g_1}{g_2} * \frac{-E_1}{k_B * T_s} \tag{2}$$

We then gather our ratio of Grounded to Ionized Sodium atoms

Taking this further, lets find the number density of grounded Na not compared to ionized Na using the Saha equation

$$\frac{N_{II}}{N_I} = \frac{2k_BT}{P_e}\frac{Z_{II}}{Z_I}\left(\frac{2\pi m_e k_B T}{h^2}\right)^{3/2} e^{-\chi/k_BT} \tag{3}$$

Now finding the total column density

$$Cden = n * (1 + ratio_1) * (1 + ratio_2) \tag{4}$$

Where Ratio 1 and Ratio 2 are respectively the grounded and ionized Na atoms Finally, finding the abundance in astronomers terms and physicists terms, with help from the example code

$$phys_{ab} = \frac{n}{n_H} \tag{5}$$

$$astro_{ab} = 12 + log(\frac{n}{n_H}) \tag{6}$$

3 Results

That was a lot of calculation, now lets analyze exactly what we gathered from the calculations of Ian Luckeydoo, We first gathered that there are 0.044 ionized sodium atoms to ground state sodium atoms.

We then find that there are 2510 ionized atoms to neutral, and naturally following we get $2.16 * 10^{18}$ per cm^2 (Column Density)

The calculated abundances are as follows (rounded to 3 decimal points)

- Astronomers abundance =
$$\frac{1.248 * 10^{-9}}{cm^2}$$
- Physicist abundance =
$$\frac{0}{cm^2}$$

Our results all fall within reasonable measure and align with our assumptions,

4 Conclusion

In this study, we analyzed the solar sodium doublet line to better understand the abundance and number densities of sodium atoms under solar conditions. This study can be improved by giving a wider range of data, possibly comparing these particular compositions to gases found on Earth to further understand a trend or division between stellar and planetary makeup

These findings highlight the value of such analyses in not only stellar science, but planetary as well, providing insights into other stars. By applying this approach to stars beyond our solar system, we can uncover trends and identify stars with compositions and conditions similar to our Sun. This could play a key role in the search for planets with potential habitability, expanding our understanding of exoplanet environments and their viability to support life.

4.1 Equations index

- Equation 1 is a simple energy equation we use to help get us the ratio, since the energy to transition to an excited state is directly proportional to λ
- Equation 2 is a form of the Boltzmann equation, comparing the excited states and ground states with their energy levels degeneracy which we talked briefly about earlier. g in this case defines a number of distinct quantum states that have the same energy level, therefor a higher g, with a higher number of similar energy levels will help account for a higher ratio
- Equation 3 The Saha equation is one we spoke of in lecture, it is an important tool for finding the ratio of ionized sodium atoms to neutral sodium atoms in our specific case. Analyzing such factors as Temperature, Electron Density, and Ionization energy
- Equation 4 is column density, by taking our ratio of neutral sodium atoms and excited sodium atoms and multiplying them by our ground state density
- Equation 5 and 6 are abundances found in the example code the numbers from these two equations differ primarily due to the scaling, physical scale is linear meanwhile astronomical scale is logarithmic