Spectral Analysis of the sun and sky

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ABSTRACT

Understanding the spectrum of sunlight is fundamental to the fields of astronomy and astrophysics. This lab report aims to analyze the spectrometer data obtained from the Sun, explore the underlying physical phenomena such as Rayleigh scattering and Fraunhofer lines, and analyse the spectra of clear and cloudy skies[1].

1 Introduction

1.1 Black Body Radiation

Black body radiation is the theoretical spectrum of electromagnetic radiation emitted by an idealized object that absorbs all incident radiation and re-emits energy uniformly in all directions. The Sun approximates a black body with a surface temperature of about 5778 K, emitting radiation across a broad range of wavelengths. The intensity of this radiation follows Planck's law, which is expressed as:

$$I(\lambda,T) = \frac{2hc^2}{\lambda^5}\frac{1}{e^{\frac{hc}{\lambda k_B T}}-1} \tag{1}$$

where $I(\lambda,T)$ is the spectral radiance, λ is the wavelength, h is Planck's constant, c is the speed of light, k_B is Boltzmann's constant, and T is the absolute temperature.

1.2 Absorption and Emission Spectra

When light passes through a gas or a plasma, specific wavelengths are absorbed by the atoms or molecules, causing electrons to jump to higher energy levels. This results in an absorption spectrum characterized by dark lines or bands at those wavelengths. Conversely, when electrons fall back to lower energy levels, they emit light at specific wavelengths, creating an emission spectrum. Both spectra provide critical information about the composition and physical conditions of the Sun's atmosphere.

1.3 Rayleigh Scattering

Rayleigh scattering occurs when light is scattered by particles much smaller than its wavelength. This scattering process is inversely proportional to the fourth power of the wavelength, which explains why shorter wavelengths (blue light) are scattered more than longer wavelengths (red light). In the context of solar observations, Rayleigh scattering contributes to the sky's blue appearance and the Sun's reddening at sunrise and sunset.

1.4 Fraunhofer Lines

Fraunhofer lines are dark lines in the solar spectrum caused by the absorption of specific wavelengths by elements in the Sun's atmosphere. Named after the German physicist Joseph von Fraunhofer, these lines are fingerprints for various elements, such as hydrogen, helium, and iron. Scientists can determine the Sun's composition and other stellar properties by studying Fraunhofer lines.

2 Experimental Setup and Results

I used the Stellarnet BLUE-Wave VIS50 spectrometer, using the Direct Normal Solar Irradiation (DNSI) method. Multiple readings were taken from the entrance of the SSE building.

2.1 Solar Spectrum

I took multiple datasets of the sun at 17:30 hrs. I was able to get a relatively good signal. I then plotted the data against the ASTM G173 data. ASTM G173 is a standard from ASTM International that provides reference solar spectral irradiance data.

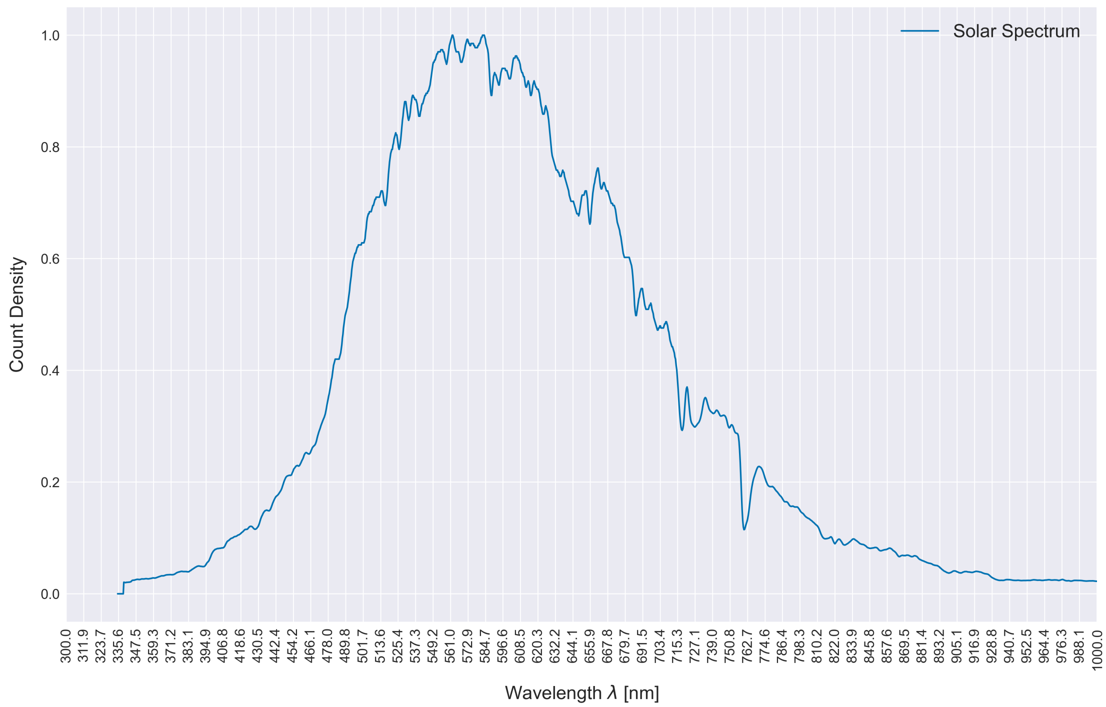

Figure 1. Solar Spectrum

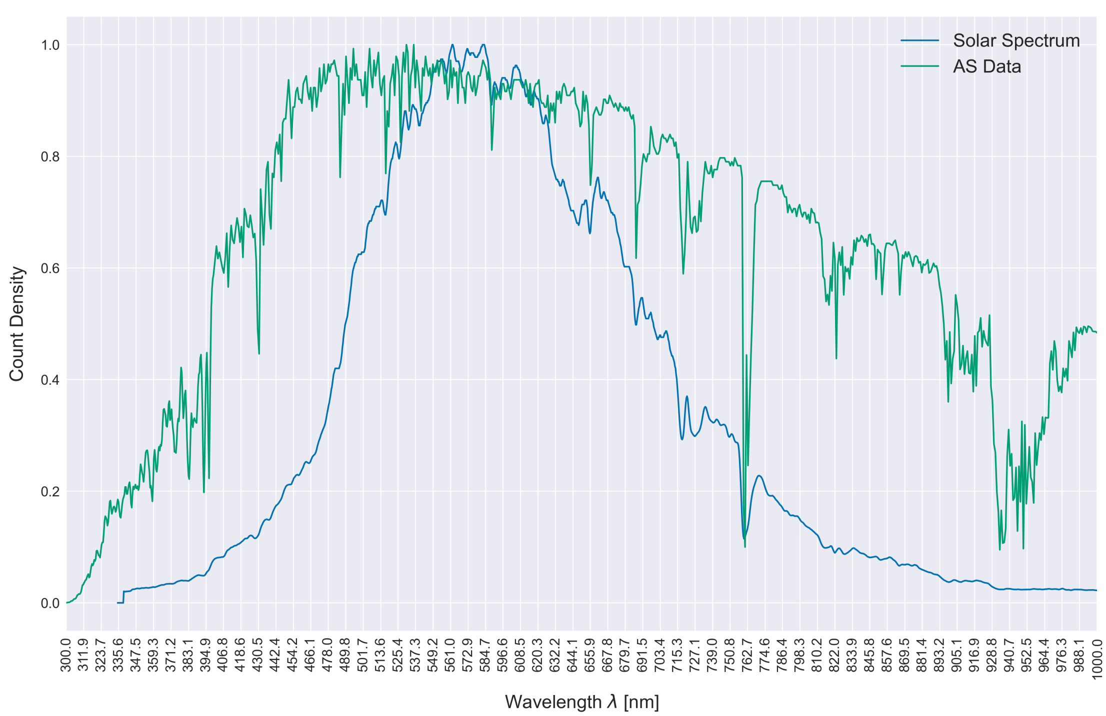

Figure 2. Solar Spectrum with ASTM G173 data

Line	Element	Wavelength (nm)	Line	Element	Wavelength (nm)
y	O_2	898.765	c	Fe	495.761
Z	O_2	822.696	F	H	486.134
A	O_2	759.370	d	Fe	466.814
B	O_2	686.719	e	Fe	438.355
C	H	656.281	G'	H	434.047
a	O_2	627.661	G	Fe	430.790
D_1	Na	589.592	G	Ca	430.774
D_2	Na	588.995	h	H	410.175
D_3 (or d)	He	587.5618	H	Ca^+	396.847
e	Hg	546.073	K	Ca^+	393.366
E_2	Fe	527.039	L	Fe	382.044
b_1	Mg	518.362	N	Fe	358.121
b_2	Mg	517.270	P	Ti^+	336.112
b_3	Fe	516.891	T	Fe	302.108
b_4	Mg	516.733	t	Ni	299.444

Table 1. Fraunhofer lines in the solar spectrum, including elements and their corresponding wavelengths.

Comparing the Fraunhofer dips in the plot to the values in the table; we can identify certain elements present in the sun's chromosphere. The peaks occur at the following wavelengths

Wavelength	Element	Wavelength	Element	Wavelength	Element
430	Fe, Ca	437	Fe	466	Fe
516	Fe, Mg	527	Fe	531	-
539	-	568	-	558	-
587	Na	593	-	600	-
612	-	615	-	623	O_2
634	-	647	-	656	H
685	O_2	700	-	717	-
726	-	759	O_2	-	-

Table 2. Identified Lines

2.2 Sky Spectrum

I carried out the spectral analysis of the sky on two different days when with an overcast. The gasses in the atmosphere tend to scatter sunlight through a process called Rayleigh scattering. Rayleigh scattering is an elastic process, meaning that the photons that hit the atmospheric gas molecules and the subsequently scattered photons have the same wavelength. The molecules do not absorb the photons and are scattered in a purely physical process. All this is to say that the energies of scattered photons do not change.

The clear sky has the bulk in the 'blue' region of the visible light, and the grey sky is more on the 'green' end of the spectrum, explaining the colours we see.

3 Discussion

The experiment, while yielding satisfactory results, requires further refinement. Enhancements in the experimental procedure and the use of more sensitive apparatus could significantly improve the quality of the data. Additionally, collecting more data sets at various times throughout the day will provide a better understanding of the underlying patterns. Attention is needed to identify and analyze the unidentified dips in the data.

References

1. Shamsi, S. & Anwar, M. S. Identifying absorption lines in blue sky and solar spectra. *PhysLab, Sch. Sci. Eng. Lahore Univ. Manag. Sci.* (2023). *shoaib.shamsi@lums.edu.pk and sabieh@lums.edu.pk.

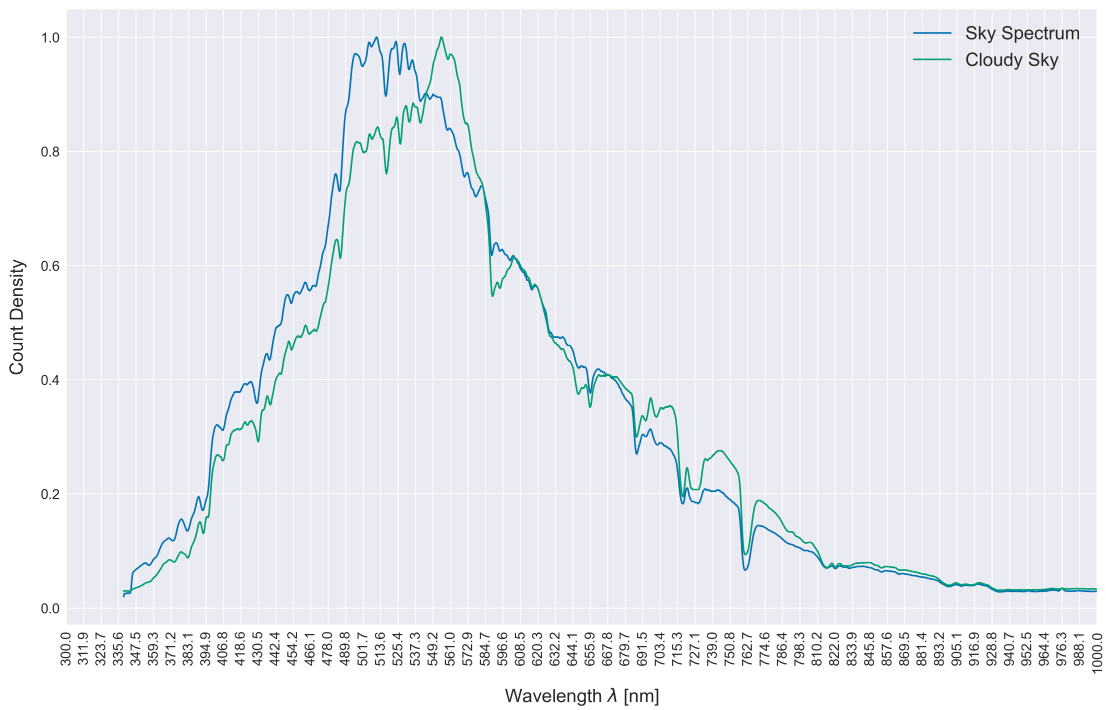

Figure 3. Spectrum with and without clouds