ASTR 101 Lab 2 Spectra

Exploring the Night Sky (University of Victoria)

Objective

The primary objective behind this lab is to learn how spectroscopy works. From this we then learn how we can use the knowledge gained from spectroscopy and apply it towards astronomy.

Introduction

As light behaves as both a wave and a particle it is necessary to use a spectrograph to view the wavelike nature of light. Using a spectrograph, we are able to view the photons, and how they behave in this wavelike manner to produce the atomic spectra.

The properties associated with these include the wavelength of individual photons. Wavelength is measured from crest to crest, or trough to trough. In the electromagnetic spectrum we can see a wide variation within the wavelengths presented. No matter the size of the wavelength they all carry energy. The higher the wavelength is than the lower the energy that it is carrying. In contrast to that, a smaller wavelength will have a higher level of energy.

Within the electromagnetic spectrum there is only a small section that is visible light. This spectrum exists between 4000 angstroms (Å) and 7000 Å. Within this spectrum each wavelength corresponds to a different colour. In example green is around 5000 Å, while red is around 6500 Å. This lab and all data presented within it exist within the visible spectrum of light.

The spectra observed within this lab can be identified as one of these three:

1. Continuum – Wavelengths in this spectrum can vary in intensity and show the full emission of visible light. Objects that emit a continuum within the visible spectrum of light are known as a blackbody light.
2. Absorption Line – When a photon passes through a gas, it collides with the electron within the atoms. This induvial electron will absorb a photon and transfer the energy, causing it to jump into an excited state. When excited the electron will jump to an outward shell in the atom. The result of this absorption is an interruption in the complete spectrum of light. The energy absorbed correlates to where on the continuum spectrum we would see a black line. That black line tells us what gas it was that the light has passed through.
3. Emission Line – Similar to an absorption line spectrum, an emission line is dependent upon the atoms of a gas that photons pass thought. The major difference, however, is that when an electron loses energy, the result is an emission of energy in the form of a photon. The result from this loss of excitement in the atom creates a black spectrum that showcases what the element was that excited the photon in a reverse image of the absorption line. Instead of a colourful spectra with missing black lines, you have a black background that showcases only the coloured lines that correlate to the gas that excited the photon originally.

These line spectrums can be useful for astronomers in that they can show us the composition of extraterrestrial bodies. This is what is known as spectroscopy. As each element has it’s own unique emission and absorption line spectrums, scientists can exploit the use of light and determine what elements lie within and beyond our solar system. They can also discover whether these objects are moving towards or away from us by determining if the line spectrums are either blue or red shifted; this is known as the Doppler effect. If a line spectrum is blue shifted it means that the object is moving closer to Earth. In comparison if the line spectrum is red shifted, it is moving away from the Earth.

Observations, Tables, Graphs

Table 1: Helium Spectrum Wavelengths and Line Positions

Line Number	Wavelength (Å)	Line Position (Pix)	Description
8	3889	238	Deep violet
7	4471	272	Bright blue-violet
6	4713	288	Faint blue-violet
5	4922	300	Blue-green
4	5016	306	Blue-green
3	5875	361	Yellow
2	6678	413	Pale red
1	7065	439	Dark red

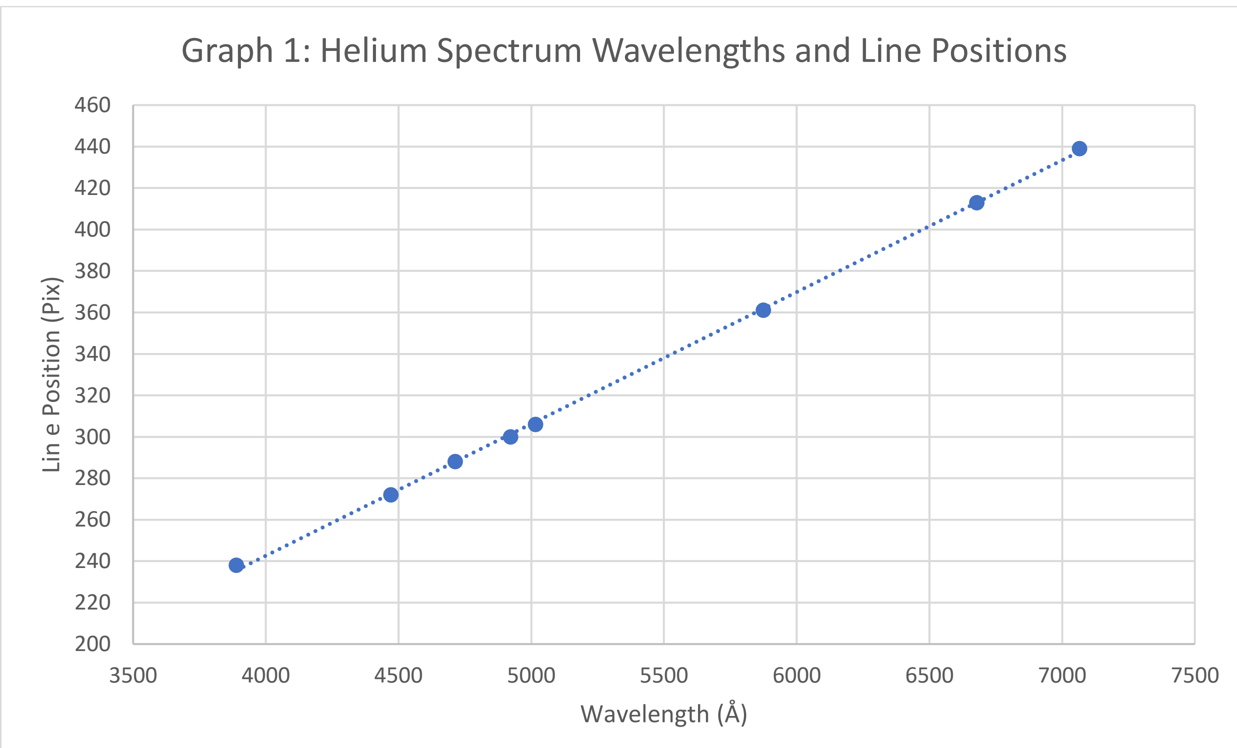


Table 2: Hydrogen Emission Line Measurements

Balmer Line	Line Position (Pix)	Wavelength (Å)	Description
Hα	**410**	**6620**	**Bright red**
Hβ	**302**	**4925**	**Blue**
Hγ	**269**	**4420**	**Faint blue**

<u>Answers</u>

1. When the lamp is at a lower temperature, the frequency is peaking in the red region of the spectrum. As the lamp's temperature is increased, the frequency increases as well. With this increase in temperature and frequency the peak of the spectrum is now in the green region of the spectrum.
2. The fluorescent lamp is emitting light in the visible emission ranges as that is the gas that is being heated to produce the light. The chemical coating that covers the lamp is what takes those emission lines and spreads them out to create a white light. Therefore, we can see both a continuum spectrum, as the visible light is a white light, and an emission spectrum, the actual source of the light within the lamp being caused by a heated gas.
3. Spectrum 1: Spectrum 1 is Sodium (Na). It has a collection of blue and violet emission lines on the left. Further towards the middle there is one green/yellow emission line and one bright yellow emission line. The most recognizable feature of this element from the others for this section was the lack of any red emission lines.

   Spectrum 2: Spectrum 2 is Hydrogen (H). It is comprised of a single pale violet and pale blue emission line, followed by a bright light blue emission line, and at the end a bright red emission line. The unique quality that made this element stand out was the intensity of the light blue and red spectra, with nothing in between the two.

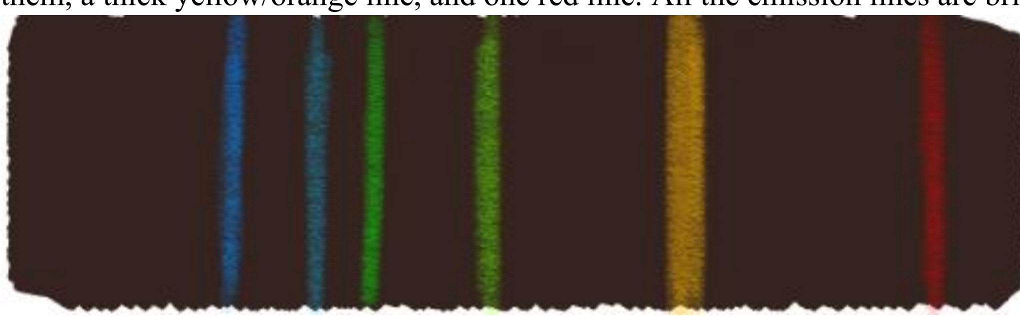
   Spectrum 3: Spectrum 3 is Oxygen (O). It consists of one violet and blue emission line, followed by three green emission lines, there is a small gap and then we see a shift from 2 yellow emission lines, to 3 orange, and finally 5 red emission lines. Of these 5 red emission lines the first two are double the width of the other emission lines. These two think emission lines helped it to stand out from the other elements.

   Spectrum 4: Spectrum 4 is Nitrogen (N). It consists of one bright violet emission line right near the start of the spectrum. Following shortly is one light blue line, followed closely by another three lines that are clumped together and are also bright blue. Slightly later there are two bright green lines close together. Following that is one thick yellow emission line, then two standard emission lines that are close together. Towards the end of the spectrum there is a collection of five red emission lines that appear as thick, standard, thick, a gap, another thick line, a small gap, and then another standard emission line. The giveaway to discovering which element this was the unique patter of red emission lines.

   Spectrum 5: Spectrum 5 is Iron (Fe). It appears to be closer to a continuum spectrum as it has emission lines that cover nearly the entire range from violet to dark blue. After dark blue there is one blue emission line, and then one light blue emission line. There is then another large clumping of emission lines throughout light blue up to the yellow colour within the spectrum. There are then five yellow emission lines spread out further apart. Then there are three orange lines spread evenly apart, followed by four closer together. After another gap there are four red emission lines close together, then a fainter red emission line, two bright emission line, a faint emission line, a large gap, another faint emission line, and a bright red emission line towards the very end of the spectrum. The giveaway for this element was its large collection of spectral emission lines that appeared almost as a continuum.

Spectrum 6: Spectrum 6 is Mercury (Hg). The spectral emission lines for mercury consist of three violet emission lines at the start of the spectrum. Following that is one thick dark blue emission line. Towards light blue there are 2 very thin emission lines, and then one thicker light blue line. There are then two thin green lines, a gap, three standard green emission lines, another gap and then one standard, one thin, and two standard emission lines. There is then a thicker emission line that appears to be a green-yellow hue. There are then two emission lines that are split nearly evenly between that line and a collection of three closely clustered yellow emission lines. Then there are two thin emission lines clustered close together. Following a gap there is one light orange emission line, one orange emission line, and then at the end of the spectrum there are two red emission lines that are further apart. To help identify this element I was looking for the collection of close together thin emission lines around the light blue region.

4. My favourite chemical element is Carbon as it is the basis for life on Earth. Its spectrum consists of one light blue line, one lighter blue, two green lines with a break between them, a thick yellow/orange line, and one red line. All the emission lines are bright.



5. These absorption lines are referred to as Fraunhofer lines. They are the absorption lines of the different gases that make up the Sun's atmosphere.[1]
6. Two of the major absorption lines within the Solar spectrum are Oxygen and Hydrogen.
7. The presence of absorption lines for both Oxygen and Hydrogen provides us a rough estimate of the suns age, by analyzing the fuel that is available for the Sun to burn. The relation of these two elements tells us that the sun was formed approximately 4.6 billion years ago.[2]

[1] Editors of Encyclopedia Britannica, "Fraunhofer Lines," *Encyclopedia Britannica*, June 11, 2018. Accessed May 20, 2021. https://www.britannica.com/science/Franhofer-lines.
[2] Ken Croswell, "An Elemental Problem with the Sun," *Scientific American,* July 11, 2020. Accessed May 25, 2021. https://www.scientificamerican.com/article/an-elemental-problem-with-the-sun/

8. Using the app, the colour of Betelgeuse should be a faint red colour. Its wavelength peak is at 8280 Å.
9. Betelgeuse is classified as a red supergiant of spectral type M1-2. Using the app, I determined that Betelgeuse should have a red hue to it, and it does.[3]
10. Using the web application Sirius should be a white star. Its peak wavelength is at 2898 Å.
11. Sirius classifies as a type A0 or A1 star depending on the system used. This lines up correctly with the app that showed that Sirius encompassed the full visual range of the spectrum to create a white light.[4]
12. For a star that peaks in the green visual spectrum the surface temperature should be 5000 Kelvin, with a peak wavelength of 5769 Å.
13. Spectroscopy helps us to understand the makeup of extrasolar planet atmospheres. Through this we can determine information about the age of the planet, how it was formed, and what we could expect the surface to look like. We can see examples of spectra that consist of Potassium, Hydrogen, and Helium. The difficulties associated with this kind of spectrograph revolve primarily around the large distances required for the light to travel. It is difficult to examine something small that is far away, which is why most of the extrasolar planets that have been examined so far are large body gaseous planets, instead of terrestrial planets.[5]
14. My measured wavelength for $H\alpha$ is 6620 Å, $H\beta$ is 4925 Å, and $H\gamma$ is 6620 Å.
15. My differences between the standards and my measurements were 80 Å for $H\alpha$, 64 Å for $H\beta$, and 57 Å for $H\gamma$. My differences varied between all three measurements. The most discrepant from the standard value was $H\alpha$ with a discrepancy of 80 Å.
16. One source of possible measurement uncertainties is the points at which I am measuring between within the GIMP software. My measurements could be taken at the beginning of an emission line, but other individuals could just as easily be taken at the midpoint, or the end of an emission line. Another possibility for error is in then using this data to create the Wavelength and Line Position chart used for questions fourteen and fifteen. If my data was off by even a small margin, my answers for those questions would be skewed as well. These uncertainties can be reduced by establishing a clear set of guidelines as to where on each emission line our measurements should be taken and by double checking all measurements to ensure accuracy.

Discussion

The study of spectroscopy can be extremely useful to astronomers. In examining the light passing through interstellar gas clouds, stars, or the atmospheres of planets, scientists can determine what elements make up our universe. These spectrums provide information on the

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[3] "Betelgeuse," *Wikipedia,* Wikimedia Foundation, May 22, 2021. Accessed May 25, 2021. https://en.wikipedia.org/wiki/Betelgeuse
[4] "Sirius." Wikipedia. Accessed May 25, 2015. https://en.wikipedia.org/wiki/Sirius
[5] Adam S. Burrows, "Spectra as Windows into Exoplanet Atmospheres," *Proceedings of the National Academy of Sciences of the United States of America,* National Academy of Sciences, September 2, 2014. Accessed May 25, 2021. https://www.pnas.org/content/111/35/12601

relative temperature of an object, and a Doppler shift in the spectrum can further be used to determine whether that object is moving toward or away from the Earth.

Conclusions

In using a relatively simple technology we can discover a great deal about our solar system and the objects that exist beyond it. With the different and unique emission and absorption lines we can gain detailed information about what materials make up our universe and the motions of those objects in space as they relate to the Earth.

References

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