Lab 3 - Spectra of Gases submitted

Exploring the Night Sky (University of Victoria)

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ASTR 101, B03

May 2018

Lab 3 – Spectra of Gases

Objective

In this lab, I had learned about the atomic spectra of multiple gasses, light sources, and the Sun. Using tools provided in the lab, I had observed these spectra and explored their greater used in the study of astronomy.

Introduction

When studying light, it is clear it has unique characteristics. Light has been observed to behave as both a wave and a particle; in some experiments, it can act prominently as either or. In this matter, light can be understood as little 'packets' of waves known as *photons*. For this lab, we used the wavelike properties of photons to produce the atomic spectra.

These properties include the wavelength of the individual photons. *Wavelength* is measured from crest to crest – or, alternatively, trough to trough. In the electromagnetic spectrum we see there is a wide range of these wavelengths. On one end, radio waves can have wavelengths as long as buildings are tall. Opposite that, gamma rays have wavelengths so miniscule that they are the size of a proton in an atom. All these waves carry energy, and the more energy a wave has, the shorter the wavelength will be.

A small section of the electromagnetic spectrum is known as visible light. This includes the wavelengths that humans and other primates have evolved to see. This section of light involves wavelengths between approximately 4000 and 7000 *angstroms* (Å, where 1Å = 10^{-10}m). Recall that shorter wavelengths correspond to the energy carried by the wave. The shortest visible wavelength is around 4500Å and is seen as a blue-indigo colour. The longest is 6500Å and is seen as the colour red. This lab and its data sit within the visible light spectrum.

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

1. *Continuum* – Wavelengths in this spectrum vary in intensity and result in a full rainbow. Objects that emit a continuum that peaks in a section of the electromagnetic spectrum is known as a 'blackbody.'
2. *Absorption line* – When a photon passes through a gas, it collides with the electrons within the atoms. The individual electron will absorb a photon and transfer the energy into a 'jump' in energy states; the electron gets more excited and continue to exist in an outward shell in the atom. The result of this absorption is an interruption in a spectrum. The energy absorbed correlates to where on the continuum spectrum we would see a black line. For example, if a wavelength of 5000Å is absorbed, a black line would be visible in green.

3. *Emission line* – Like an absorption line spectrum, an emission line is dependent on the atoms of a gas that photons pass through. However, the major difference is when an electron loses energy, the result is an emission of energy in the form of a photon. The result is a black spectrum with spikes in colour.

These line spectrums are useful for astronomers to determine the elemental composition of extraterrestrial bodies. This is known as *spectroscopy*. Because each element has its own emission and absorption line spectrums – like a fingerprint – scientists can exploit the use of light and figure out what elements lie within and beyond the solar system. They can also determine the direction of movement of interstellar bodies by observing if the line spectrum is red shifted or blue shifted. This is known as the *Doppler Effect*; if the line spectrum is blue shifted, the object is moving closer to Earth; if the line spectrum is red shifted, the object is moving away from Earth.

<u>Procedure</u>

To begin the lab, I had established the tools and technology I would be using. The tools I used in this lab are:

- A 5-Megapixel camera, resolution 720x1280 in a Samsung Galaxy A5 smartphone
- Hand-held diffraction grating, 600 lines/mm
- A spectrograph (camera with diffraction grating integrally mounted)
- 3 light sources
    - An incandescent light
    - A florescent light
    - Sunlight
- Gas discharge tubes containing
    - Hydrogen
    - Helium
    - Neon
    - Mercury
    - An unknown gas
- Computer with *Cheese* video program and *KRuler* measuring program

The first data recorded were the photographs of the line spectrums. By placing the diffraction grating over my phone's camera and looking slightly away from the source of the light, I could catch the photos seen in Figures 1 through 3. Figures 4 through 8 were taken with the same camera. They were produced by the spectrograph, discharge tubes, and *Cheese*. I simply took pictures of the image on the monitor.

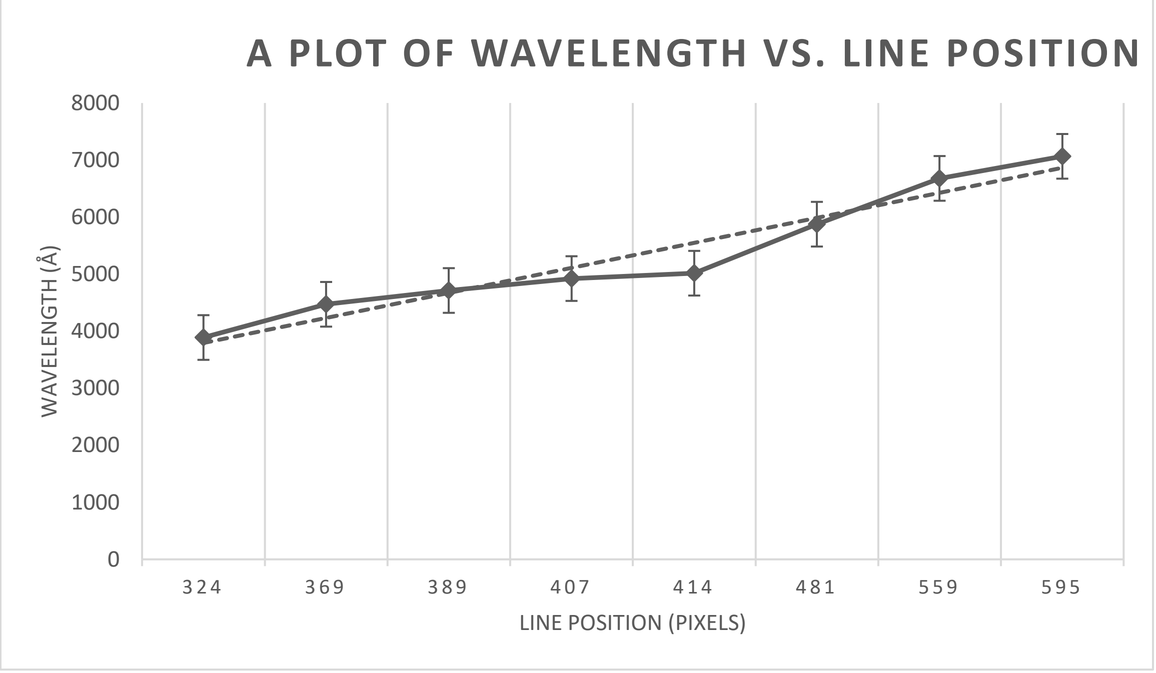
Next, using the data I collected with *Cheese*, *KRuler*, and the helium spectrograph, I filled out Line Position in pixels on Table 1. Line Graph 1 corelates with Table 1 and shows the relationship between the computer pixels and the wavelengths on the emission line spectrum

Finally, I used Line Graph 1 to complete Table 2. I used *KRuler* find the line positions of the first order of hydrogen's emission line. Then, I found the wavelength related to each line position and completed Table 2.

Observations

LINE NUMBER	WAVELENGTH (Å)	LINE POSITION (PIXELS)	DESCRIPTION
-	-	0	Zero order image
8	3889	324	Deep violet
7	4471	369	Bright blue-violet
6	4713	389	Faint blue-violet
5	4922	407	Blue-green
4	5016	414	Blue-green
3	5875	481	Yellow
2	6678	559	Pale red
1	7065	595	Dark red

Table 1 – Helium spectrum wavelengths and line positions.



Line Graph 1 – A plot of wavelength versus line position. Based upon the data from Table 1, this line graph will be used to help determine the wavelength for the hydrogen emission line measurement as seen below in Table 2.

BALMER LINE	LINE POSITION (PIXELS)	WAVELENGTH (Å)	DESCRIPTION
H_A	534	4227	Bright red
$H_ß$	385	3047	Blue
$H_Γ$	341	2699	Faint blue

Table 2 - Hydrogen emission line measurements.

Answers

1. The following are figures of the various emission spectrums explored in this lab exercise. The images in Figures 1 and 2 were produced using the hand-held diffraction grating and my cellphone camera, while the rest were taken using the gas discharge tubes, the simple spectrograph and the *Cheese* video program.

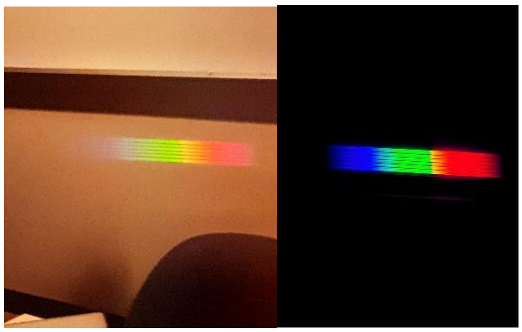


Figure 1 – Faint incandescent spectrum (left) and bright incandescent spectrum (right). The fainter, lighter spectrum does not have as intense a blue colour as the bright spectrum in the right photo. This is because there is less light, therefore less heat and energy. Blue and indigo have high-energy wavelengths, so if the incandescent lamp is dimmed, there is less energy. If it is brightened, there is more heat/energy/blue-indigo wavelengths (Ribeiro).

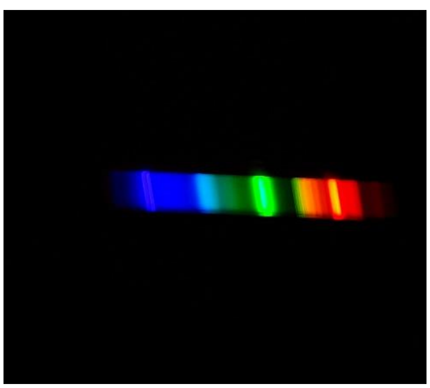


Figure 2 -Fluorescent light spectrum. Unlike the incandescent light spectrum, this is not a continuous spectrum. There are fainter areas, especially in the yellow-green area, and sharp spikes of vividness in the indigo, green, and orange-red. This light has been adjusted to have a 'natural' look as it illuminates a space. This spectrum gives a good idea as to which colours have been adjusted.

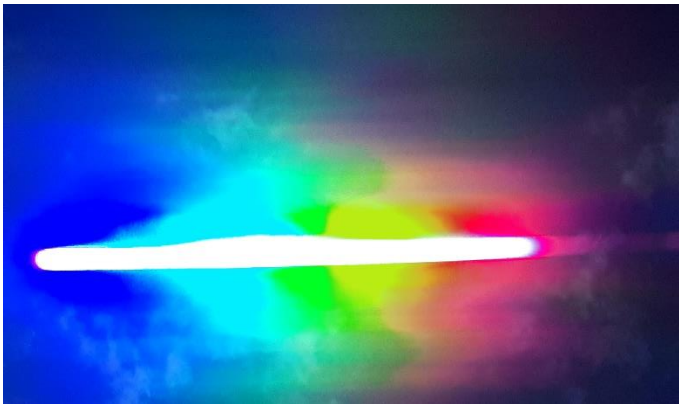


Figure 3 - Solar Spectra. With the handeld diffraction grating and my camera on my cellphone, I produced this image. My camera is far too basic to capture a proper spectrum. The brightness of the Sun overtakes the photo. However, colours from dark blue-indigo to magenta are visible.

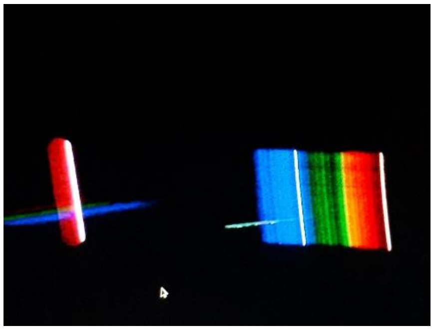


Figure 4 - Hydrogen emission spectrum. One of the simplest of the atomic light spectrums, gaseous hydrogen has two main principle spectral lines in the first order. Line 1 is in the red, and line 2 is blue.

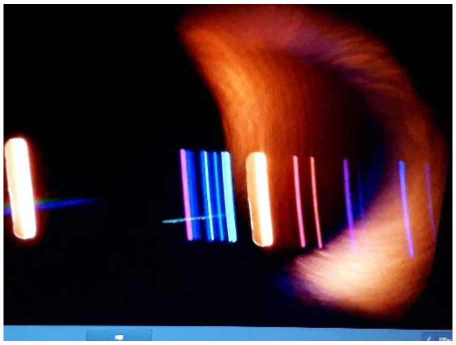


Figure 5 - Helium emission spectrum. The first order of helium has 8 principle spectral lines. Because there are so many lines, I had used helium to plot Tables 1 and 2, which gave me a better idea of the relation between emission spectrums and the wavelengths of the light.

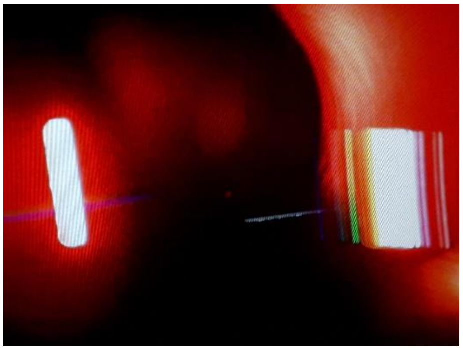


Figure 6 - Neon emission spectrum. This spectrum is very dense in the orange-red section of the spectrum. Red wavelengths are long and have very low energy. Neon is a halogen, so its electrons are going to be in their lowest state of energy, resulting in a red colour.

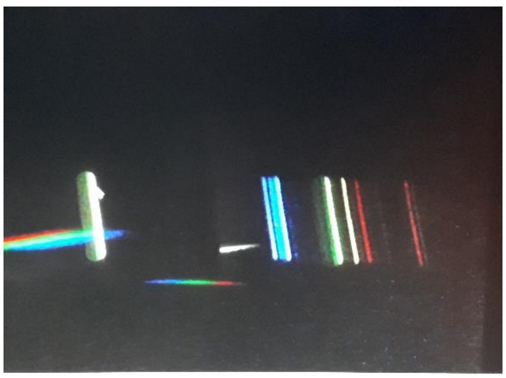


Figure 7 - Mercury emission spectrum. This metal has a very special property that makes it unique; it has a very low melting point and is liquid at room temperature (about 20°C). When at this state, elements tend to experience higher kinetic energy, meaning their atoms are moving and the electrons can exist in higher energy states. This is shown in mercury as it has a lack of low-energy red lines and higher-energy green and blue lines.

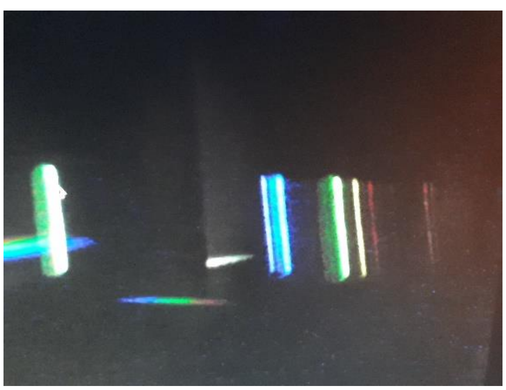


Figure 8 - Unknown emission spectrum. Myself and a partner had deduced this is mercury. The image is very similar to mercury (Figure 7) as it also exhibits the lack of low-energy red spectral lines, and higher energy electron states resulting the density in blue.

2. Starting with the incandescent light, it is a near complete continuum of spectral light, from indigo to red. The horizontal lines are resulting from the bulb's own structure. Next, the florescent light has spikes of green, cyan, and red. These colours are famous for creating artificial white light. After that there is the

emission spectrum for hydrogen. Its electron can jump from a high energy state, resulting in the blue line, and a low energy state, giving off the red line. Finally, there are helium, neon, and mercury. Each element has its own unique emission spectrum that showcases the existing energy states of the electrons in the atom.

3. The emission spectrums are what result when an electron drops from a high energy state to a lower one. In the process, it loses energy in the form of a photon. The photon could be carrying a short wavelength, giving off a blue colour, or a longer wavelength that results in red, or any variation in betreen.
4. I recognized the unknown element to be mercury. It matches the image of the confirmed mercury in Figure 7. Because the emission spectrum is unique to each element, it would be hard to find one that matches mercury.
5. The results of my measurements of hydrogen's spectral lines are much less than that of the true measurements provided in the Laboratory Manual. On average, my measurements are 2041Å less than the true measurements. I expect the difference was made by the fact that my camera and spectrograph was on an angle from the source of the hydrogen discharge gas chamber. This could have shortened the relative distances between hydrogen spectral lines, giving me the smaller measurements. This affected Tables 1 and 2 and Line Graph 1.
6. I cannot discern any important spectral lines int the solar spectrum (Figure 3). However, it is known that the Sun is a near perfect blackbody around the yellow-green section of the spectrum. With proper technology, the Sun's spectrograph would exhibit that of hydrogen, as it is mostly composed of this element.
7. With spectroscopy, we can take the light passing through extrasolar planets' atmospheres and create an absorption line spectrograph. This will show what the atmosphere is made of. A challenge with this technology would be catching the planets at the right angle from their sun or other light source – much like waiting for a solar eclipse on Earth. Or, alternatively, rogue planets are harder to catch with a light source as they do not belong to a stellar system.

Discussion

The study of spectroscopy is very useful to astronomers. By looking at the light passing through interstellar gas clouds, stars, or extrasolar planetary atmospheres and observing the emission, absorption, or continuum line spectra, scientists can determine what elements or compounds the universe is made of. These spectrums can give information on the temperature of an object, and a Doppler shift in the spectrum determines whether the object is moving toward Earth or farther away.

Conclusion

By use of the relatively simple technology in this lab, I was able to produce images of a continuum spectrum, absorption line spectra, and emission line spectra. I measured the first order of hydrogen and helium to understand how the distance between the spectra lines corelates to the wavelength of the photos being emitted.

Works Cited

Ribeiro, C. I. "Blackbody Radiation from an Incandescent Lamp." *American Association of Physics Teachers*, American Association of Physics Teachers, 1 Jan. 1970, aapt.scitation.org/doi/abs/10.1119/1.4893096?journalCode=pte.

ASTR 101 Spectra Rubric: /18 + /6 + /18 + /18 + /24 + /6 + /10(neatness) = /100

Grade Value	0	1	2	3	Weight
Objective & Introduction	Content missing	Basic content. Non-scientific jargon and wording. Difficult to understand sentences.	Acceptable content. Some attempt at scientific terminology. Sentences acceptable.	Excellent content. Proper use of jargon and scientific wording. Assumptions noted and justified.	6
Grade Value	0	1	2	3	Weight
Procedure	Content missing	Basic content. No special equipment described, minimal description of procedure, no discussion of measurement uncertainties.	Acceptable content. Special equipment noted, important points of procedure noted, basic discussion of measurement uncertainties.	Excellent content. Special equipment addressed and discussed, procedure detailed and informative, measurement uncertainties noted.	2
Grade Value	0	1	2	3	Weight
Observations, Tables & Graphs	Content missing	Basic content. Incomplete information. Tables missing title, or other details. Graphs missing titles, labels, and/or too small. Sketches lacking detail.	Acceptable content. Minor details missing from graphs, tables and sketches, but all major details present.	Excellent content. Tables and graphs complete. Observations thorough.	6
Grade Value	0	1	2	3	Weight

Answers	Content missing.	Basic content. Questions answered simplistically; answers show lack of insight. Results not clearly discussed. Units neglected. No link between objective and results.	Acceptable content. Questions mostly answered correctly. Results mentioned, with spotty units. Weak link provided between objective and results.	Excellent content. Questions answered in detail. Clear connection between objective and results. Units clearly included.	6
Grade Value	0	1	2	3	Weight
Discussion	Content missing.	Basic content. Lacking discussion about expectations, assumptions, and consistency. No discussion about broader context.	Acceptable content. Limited discussion of expectations, assumptions and consistency. Limited discussion of broader context.	Excellent content. Expectations, assumptions and consistency clearly and correctly addressed. Broader context discussed.	8
Grade Value	0	1	2	3	Weight
Conclusion & References	Content missing.	Basic content. Conclusion unclear or lacking insight. References limited or missing.	Acceptable content. Correct conclusion but limited.Some references included.	Excellent content. Conclusion correct and focused. Detailed references included.	2