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HW 04: CHARACTERIZING THE CONTINUUM AND EMISSION LINES

Bryan Yamashiro[1] and Terry Salaga[2]
University of Hawaii at Manoa
2500 Campus Road
Honolulu, HI 96822

1. INTRODUCTION

Luminous sources produce spectra including both continuous and emission spectra. The continuous spectrum contains light of all wavelengths present, creating a continuum spectrum. Emission lines are emitted by hot rarefied gas at definite wavelengths corresponding to allowed electron transitions and ion capture of free electrons Wyatt (1974). Each stage of ionization of every chemical element has its own individual pattern of emission lines and serves as a unique footprint of the source.

This study examined the spectra of unknown emission sources, and the elemental composition of the unknowns. The spectra in question contains both continuum and emission lines. Another property that will be determined is the temperature of the unknown. Temperature will be determined by an application of Wien's law, provided in equation 1. Wein's law expresses the relationship of the wavelength at which a black body emits the greatest amount of energy against an inversely proportional absolute temperature Wyatt (1974). The Wein displacement constant, W, is found by differentiating the black body intensity (B_λ) with respect to λ and setting the derivative equal to zero, yielding a constant of 0.289782 cm·K Aller (1963).

$$\lambda_{peak} = \frac{W}{T} \tag{1}$$

2. APPARATUS

A spectrograph allows for the separation of various wavelengths of light from a radiating source to produce a spectrum Wyatt (1974). The radiating source within the setup included a light that emitted the mystery spectra. Information of the spectra was transmitted through a fiber optics cable that was connected to the spectrograph and the opposing end was focused on the light emitter.

3. PROCEDURE AND OBSERVED QUANTITIES

The spectra of the unknown source was collected using both the spectrograph for one and four seconds. The one second spectra was chosen to isolate the intense emission line located at the center of the spectra, shown in figure 1. The four second spectra included other emission lines away from the central wavelengths. Time intervals greater than four seconds maxed out the spectrograph, so no other time interval was used. Three individual runs were carried out for the one second and four second intervals, respectively. The background and dark of the spectrograph were measured before data analysis, and these were conducted with both respective time intervals and runs. The full spectra (FS) for both one and four second intervals were then created using the averaged spectra ($\bar{S}$) and subtracting the average backgrounds ($\bar{B}$) and average darks ($\bar{D}$), shown in equation 2.

$$FS_{1,4} = \bar{S} - (\bar{B} - \bar{D}) - \bar{D} \tag{2}$$

The raw data gathered from the spectrograph, in figure 1 (left), represents the full spectra. To emulate a black body spectrum, a function was introduced to correct the data for the detector sensitivity. A quartz lamp was used to derive the response function and the sensitivity of the detector. The quartz spectrum was measured for the quartz sample using the same techniques as the mystery sample. To obtain the response function, in equation 3, a scaled flux (Q_{SFS}) was divided by the observed flux (Q_{OF}) of the quartz spectrum. The scaled flux was derived by initially by deducing the quartz specifications, finding the most wavelength of maximum intensity. This max wavelength was then scaled by the interpolated quartz specifications, producing a scaled flux.

$$R = \frac{Q_{SFS}}{Q_{OF}} \tag{3}$$

Figure 1 (right) was the generated spectra that included the sensitivity correction of the spectrograph. The continuum represented in green was included primarily to introduce a continuum void of emission lines. The method used to generate the continuum is outlined in equation 4. Each wavelength and its corresponding count (C_i) was compared to next wavelength and count (C_f). If the difference in count (ΔC) was higher than an arbitrary specified value (x), then the average of the difference ($\overline{\Delta C}$) was considered to be the count. Contrarily, if ΔC was lower than x, then C_i was left as

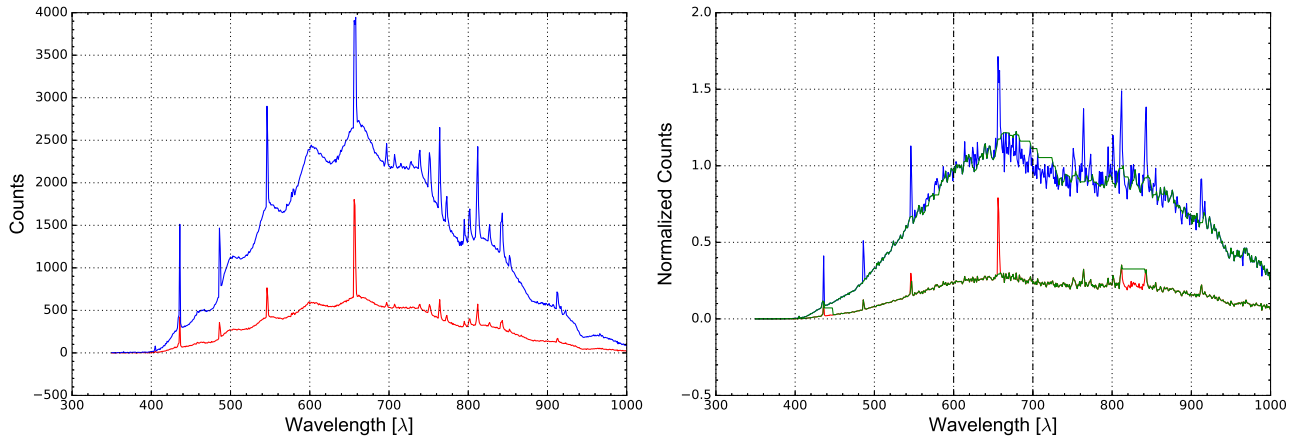

Figure 1. Full spectra for the mystery emission source with wavelength against counts. The red data represents the 1 second time interval, and conversely, the blue data the 4 second. The left spectra is the raw uncorrected data, whereas the right is the corrected spectrum that includes sensitivity corrections and count normalization. The overlaid green data represents the continuum derived to remove the emission peaks. The black dashed lines represent the region (600 nm - 700 nm) chosen to deduce the peak wavelength.

the count.

$$C = \begin{cases} C_i, & \Delta C > x \\ \overline{\Delta C}, & \Delta C < x \end{cases} \tag{4}$$

4. RESULTS

The peak wavelength (λ_{peak}), represented in equation 5, was determined through the corrected spectra and the centroid of the continuum. The centroid of the continuum lies between wavelengths 600 nm and 700 cm, so the range was concentrated between those limits. Figure refcounts clearly illustrates the necessity of the continuum, as equation peak, would have included the large emission line. The continuum acted as an impetus to more accurately estimate the peak wavelength, compared to the excessive emission flux.

$$\lambda_{peak} = \frac{\sum(\lambda \times flux)}{\sum flux} \tag{5}$$

The uncertainties of the derived wavelengths of the two runs were determined by equation 6. It is imperative to note that the uncertainty of the centroid is merely an estimate, but a powerful deduction derived from equation 5.

$$\sigma^2_{\lambda_{peak}} = \frac{\sum((\lambda - \lambda_{peak})^2 \times flux)}{\sum flux} \tag{6}$$

Utilizing equations 5 and 6, the peak wavelengths of the continuum were (650.50±28.63) nm and (651.82±28.85) nm for the 1 second and 4 second intervals, respectively. The peak wavelengths were then inserted into the Wein relation, in equation 1, and the temperatures for the 1 and 4 second intervals were determined to be (4454.76±196.06) K and (4445.74±196.77) K, all provided in table 1.

Table 1. The peak wavelength and correlated temperatures for the 1 and 4 second time intervals.

Time Interval (s)	Peak Wavelength (nm)	Temperature (K)
1	650.50±28.63	4454.76±196.06
4	651.82±28.85	4445.74±196.77

Finally, the emission lines of the mystery sample were determined using the full corrected spectra. The continuum was subtracted from the full spectra to yield just the emission lines, seen in figure 2. All peaks above the specified threshold, above 0.25 normalized counts, was chosen for emission line determination. The threshold of 0.25 normalized counts was used because that value included the most prominent peaks. Every wavelength that resulted in normalized counts over 0.25 were included in table 2. If a certain peak contained more than one consecutive wavelengths over the threshold, the values were averaged, specified by the wavelengths ending with 0.5 nm. Each emission line from the mystery spectrum were overlaid with known gas spectra, provided by the National Institute of Standards and Technology (NIST). The nine emission lines from the mystery spectrum corresponded to the known NIST gases hydrogen, mercury, and argon, shown in table 2.

5. DISCUSSION

Comparing against known NIST gas emission spectra, the mystery source was a combination of hydrogen, argon, and mercury. After corrections and normal-

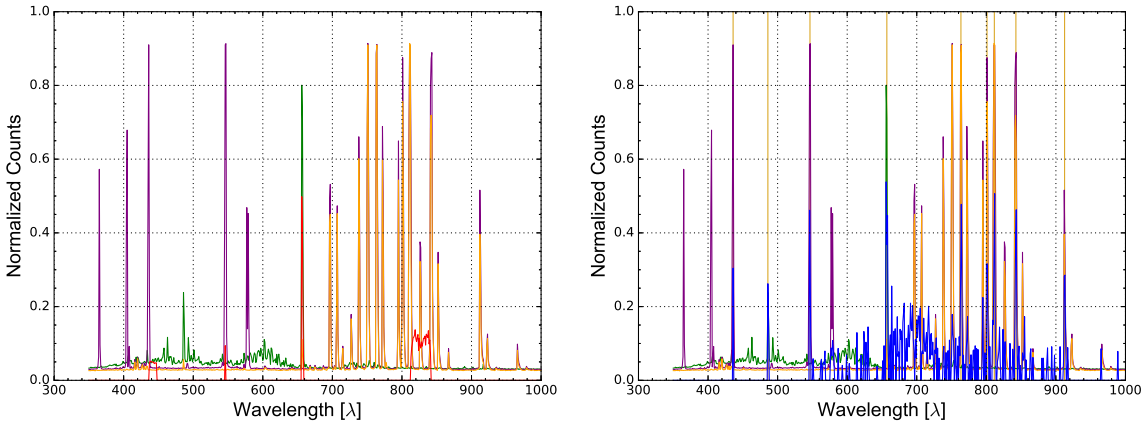

Figure 2. Emission lines from the full spectra. The plot on the left is the 1 second emission (red) and the right plot is the 4 second (blue) emission. The hydrogen emission is colored green, and the mercury and argon emission lines are purple and orange, respectively.

Table 2. Emission lines over a specified normalized count threshold of the full spectra. The emission lines are compared to known values of emission of three known spectra of hydrogen, mercury, and argon. Emission lines on the 4 second emissions above the count threshold are overlaid with goldenrod reference lines to illustrate each of the analyzed wavelengths.

Emission Line (nm)	Hydrogen	Mercury	Argon
436.0	-	-	x
486.0	x	-	-
546.5	-	x	-
657.0	x	-	-
763.5	-	x	x
801.0	-	x	x
811.5	-	x	x
842.5	-	x	x
912.5	-	x	x

ization, the continuum wavelengths of the source were (650.50±28.63) nm and (651.82±28.85) nm for the 1 second and 4 second time intervals, respectively. Wein's law provided the correlating temperatures, which were (4454.76±196.06) K and (4445.74±196.77) K, again for the 1 and 4 second intervals.

Seen in figure 2, the continuum showed a large amount of noise at around 700 nm. Figure 1 shows step-like traits on the continuum, which means that a more precise approach may have resulted in a better continuum. The method of collecting the emission lines was also crude, and Gaussian fits would've yielded more accurate wavelength measurements for each emission line.

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