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Physics 139
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Lab 7 Report

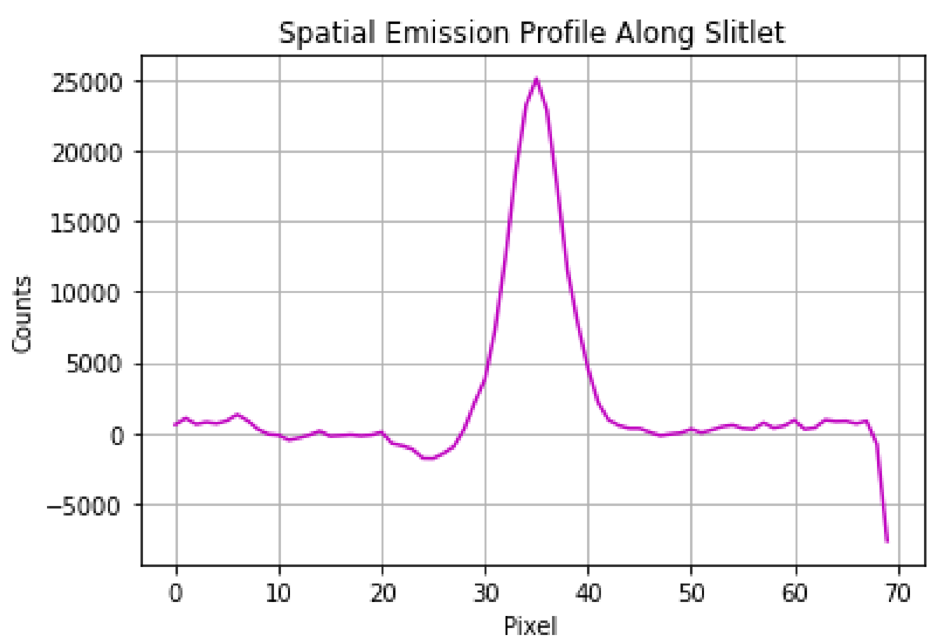
In this lab, I extract a 1D object spectrum from a reduced, sky-subtracted 2D spectrum collected with Keck/DEIMOS. I then measure the redshift of the object.

PART ONE - Inspect the Reduced Spectrum

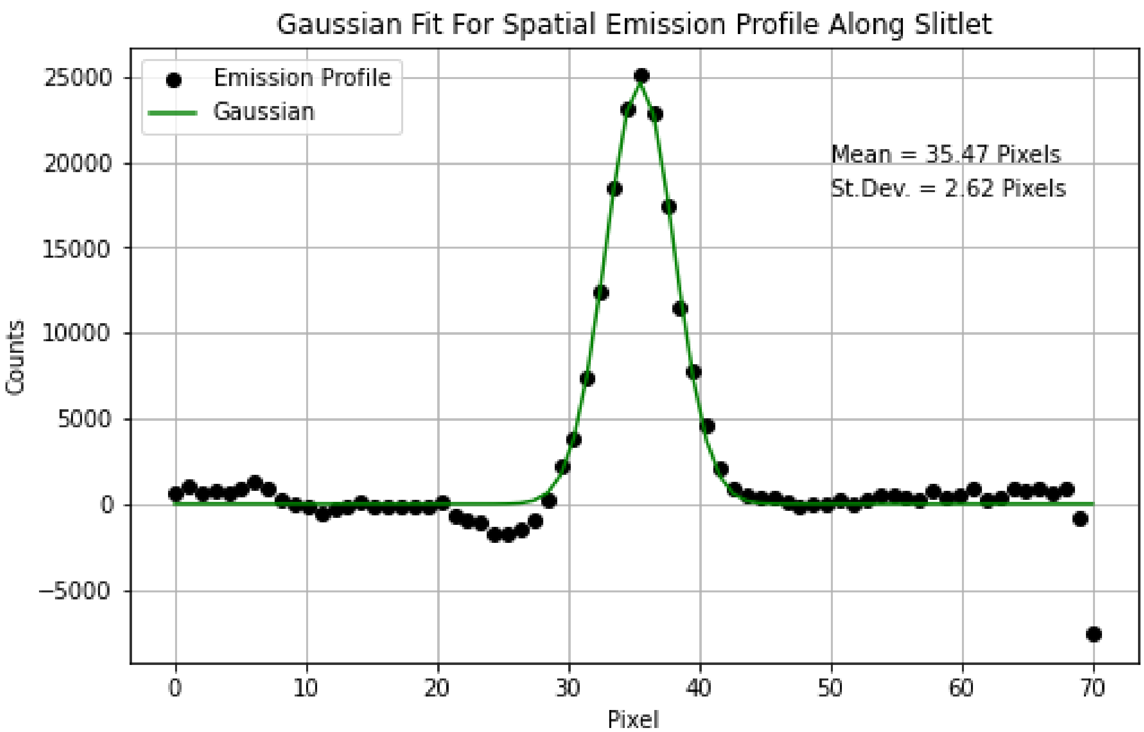
In this part of the lab, I open the given file and inspect its elements using the *fits.open()* and *info()* functions, as well as the access code provided to us in the lab document. The lab manual specifies that the provided slitlet is 70 pixels long and 4096 pixels wide. The length of 70 pixels corresponds to a length of 8.295 arcseconds since the pixel scale is 0.1185 inches per pixel. The dispersion for the spectrum in units of Å per pixel is 0.324 Å/pixel.

PART TWO - Determine the Location of the Object

In this part of the lab, I determine the location and extent of the object emission. To do this, I created a function called *func()* that sums the 2D flux array along the dispersion direction and creates a 1D array of total flux as a function of spatial position along the slitlet. I used this function on the 2D flux array within the provided fits file and then plotted the spatial emission profile along the slitlet. The plot is shown below:



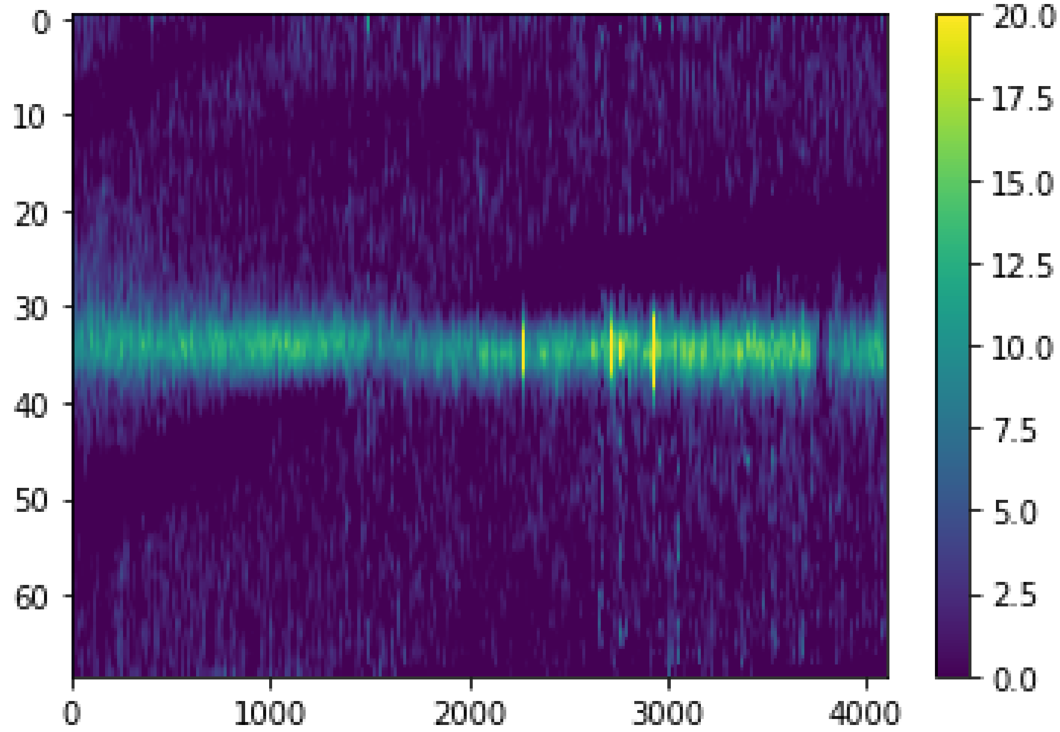
I used code provided to us in lab 6 to fit a 1D Gaussian to the plot for the spatial emission profile along the slitlet. The Gaussian Fit as well as the mean and standard deviation for the Gaussian fit are shown below:



It is clearly seen on the graph above that the object is located at ~35.48 pixels and has an extent of ~2.62 pixels in both directions.

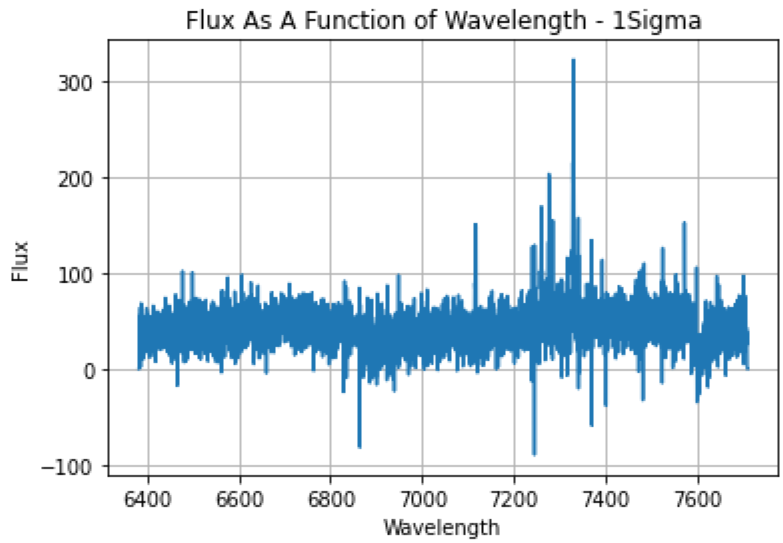
PART THREE - Extract the Object Spectrum

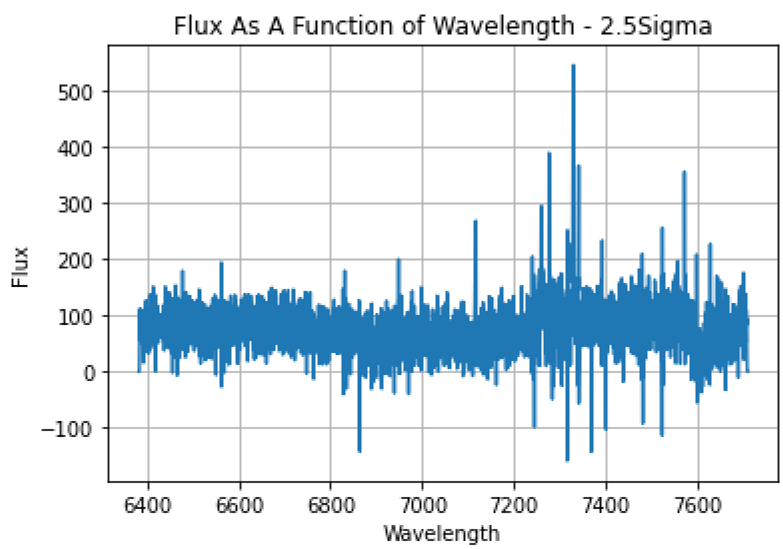
In this part of the lab, we are asked to write a routine to extract the object spectrum, creating a 1D spectrum of relative object flux as a function of pixel position (and thus wavelength). To do this, I wrote a function called *extract()* that takes the necessary information (flux, mean, wave, width) from the object spectrum and inserts it into a holder array called *flx*. To account for the tilt of the slitlet in my extraction algorithm, I interpolate the spectra in each pixel row onto wavelength values corresponding to the pixel row location of the object. I do this for every data point using a *for* loop as well as the code provided to us in the lab document, and save the newly standardized data points into a list titled *lst*. This list is now a set of flux values interpolated so as to correspond to the wave-length values in pixel row 45. The resulting image after the interpolation process is shown below:

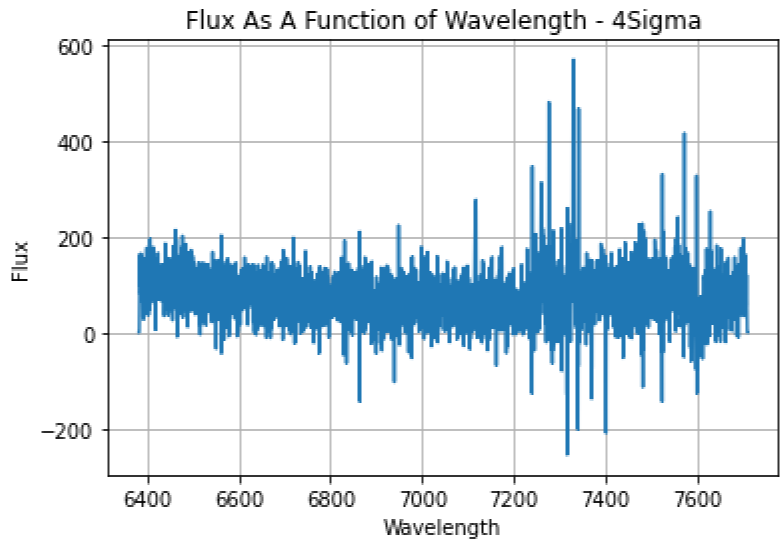


I extracted the object spectrum using 3 different sizes for the full width of the extraction window: 1σ, 2.5σ, and 4σ where σ is the standard deviation of the Gaussian fit to the spatial profile from Part 2.

The three 1D spectra (flux as a function of wavelength) are shown below:


Flux As A Function of Wavelength - 1Sigma
300
200
100
0
−100
Flux
6400
6600
6800
7000
7200
7400
7600
Wavelength

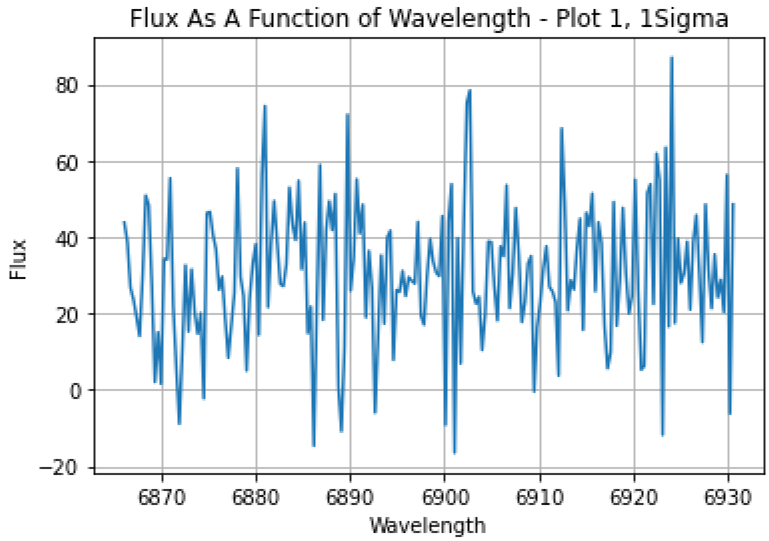

Flux As A Function of Wavelength - 2.5Sigma
500
400
300
200
100
0
−100
Flux
6400
6600
6800
7000
7200
7400
7600
Wavelength

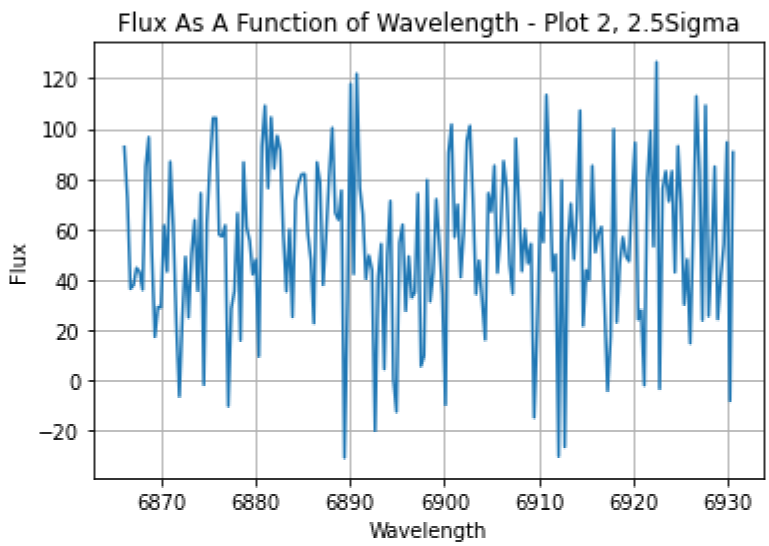


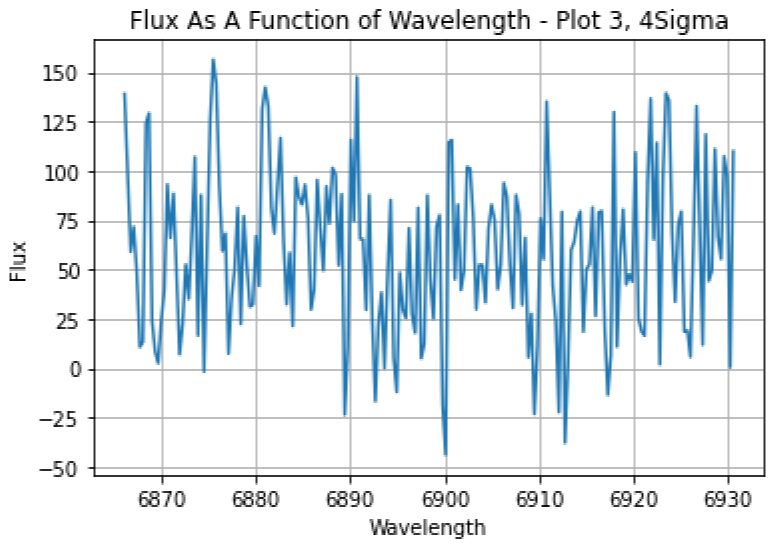
Next, for each of the resulting spectra, we are asked to select a region of at least 200 pixels in scale that is relatively free of sky line residuals. We are asked to measure the signal-to-noise of the resulting spectrum by computing the mean and standard deviation of the flux within each clean region. To do this, I wrote a function called *func2()*. First, this function splices each spectra according to specified start and end x-values, effectively creating regions that are 200 pixels long. Next, it calculates the mean and standard deviation of the slice, and calculates the signal to noise ratio (mean divided by standard deviation). It then returns the calculated mean, standard deviation, and signal to noise ratio. I used this function on each of the three spectra and recorded all the values pertaining to each one in the table below:

Extraction width (σ)	**Extraction width (pixels)**	**Mean Flux**	**Standard Deviation**	**S/N**
1	200	30.34	17.94	1.691
2.5	200	54.30	31.76	1.710
4	200	58.86	40.99	1.436

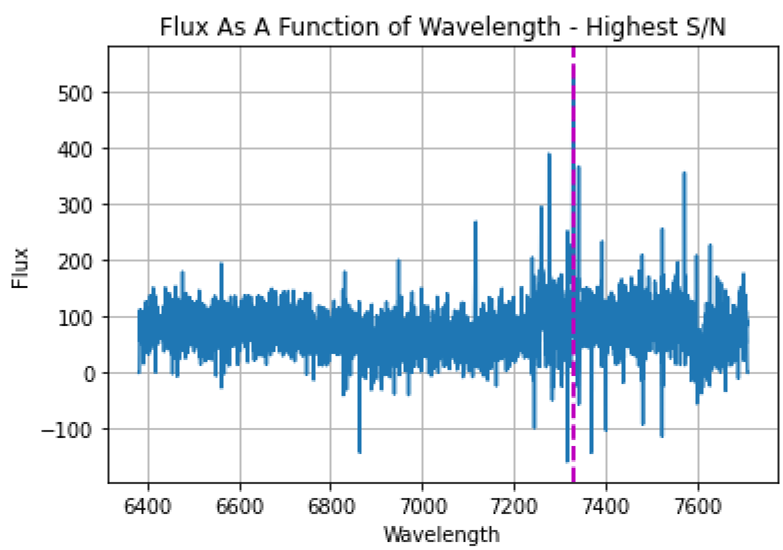
I also re-plotted the spectra after calculating the signal to noise ratios of their slices and have included those plots below:


Flux As A Function of Wavelength - Plot 1, 1Sigma
Flux
Wavelength
80
60
40
20
0
−20
6870
6880
6890
6900
6910
6920
6930


Flux As A Function of Wavelength - Plot 2, 2.5Sigma
Flux
Wavelength
120
100
80
60
40
20
0
−20
6870
6880
6890
6900
6910
6920
6930



We are then asked to use the extraction window that yields the highest signal to noise ratio to display the 1D spectrum as a function of wavelength, and discuss any notable features in the spectrum. The extraction window that yields the highest signal to noise ratio is the window for 2.5σ. I have displayed the full spectra in the plot below:

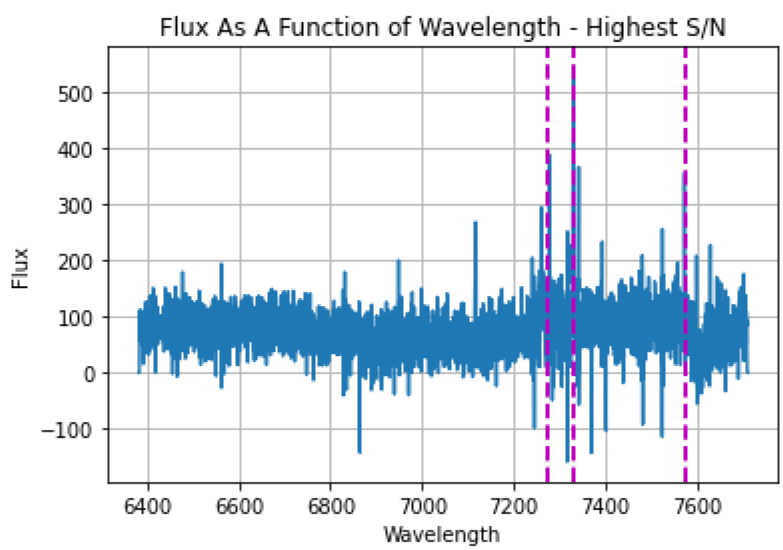


The highest peak of this spectrum is denoted by the dashed magenta line. The spectrum is homogenous in shape and is quite horizontal, but it has several peaks between the wavelengths of 7200 and 7600.

In this part of the lab, I found that S/N (signal to noise ratio) does vary with the extraction window. The largest S/N value was for the 2.5σ extraction window, and decreased for increases and decreases made to the extraction window. For a large extraction window, more sky background is let in and detected, causing the noise value of the image to increase. For small extraction windows, only a part of the emission spectrum is captured, so the signal value of the image decreases.

PART FOUR - Measure the Redshift of the Object

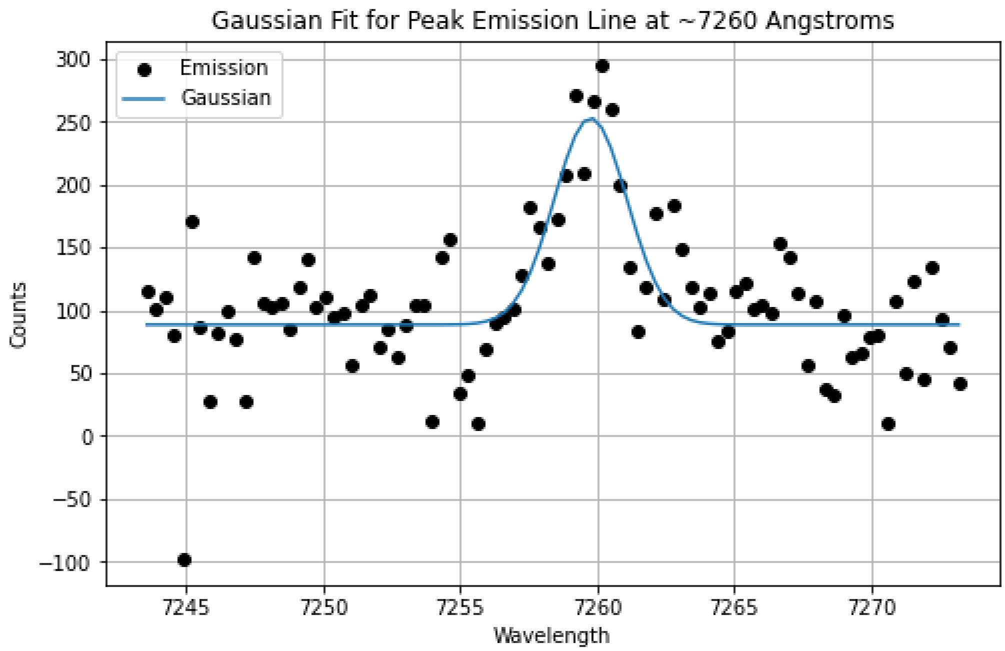
In this part of the lab, the first thing I do is find the three strongest emission lines from the extraction window that yields the highest signal to noise ratio. The three strongest emission lines are found by observing the three highest peaks on the spectrum. I found the three highest peaks at the following wavelength values: x = 7330 Angstroms, x = 7274 Angstroms, x = 7572 Angstroms. They are denoted by the dashed magenta lines on the following plot:

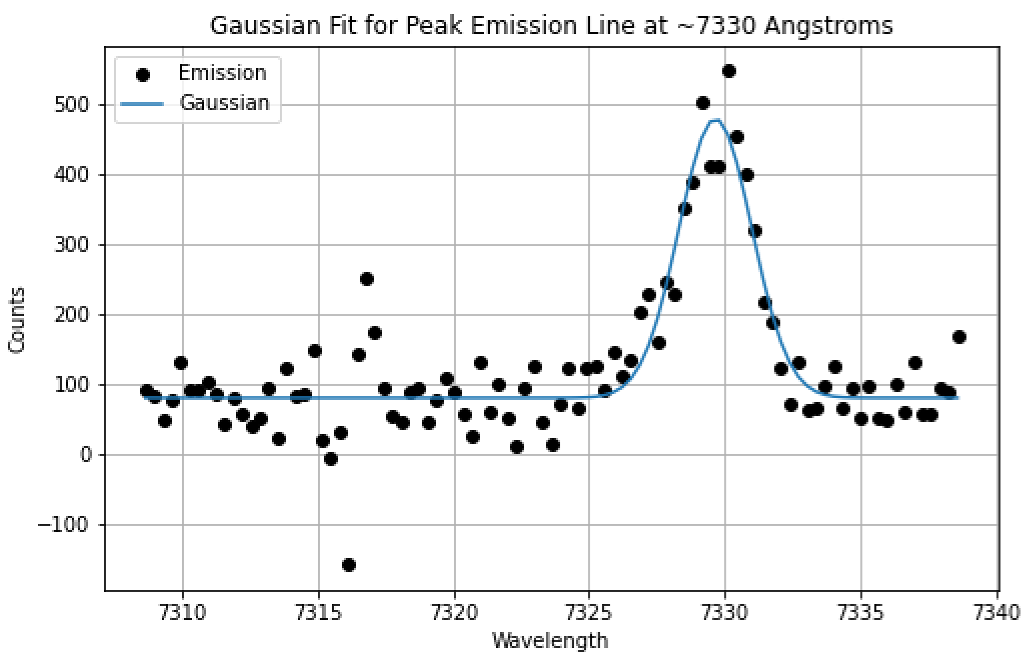


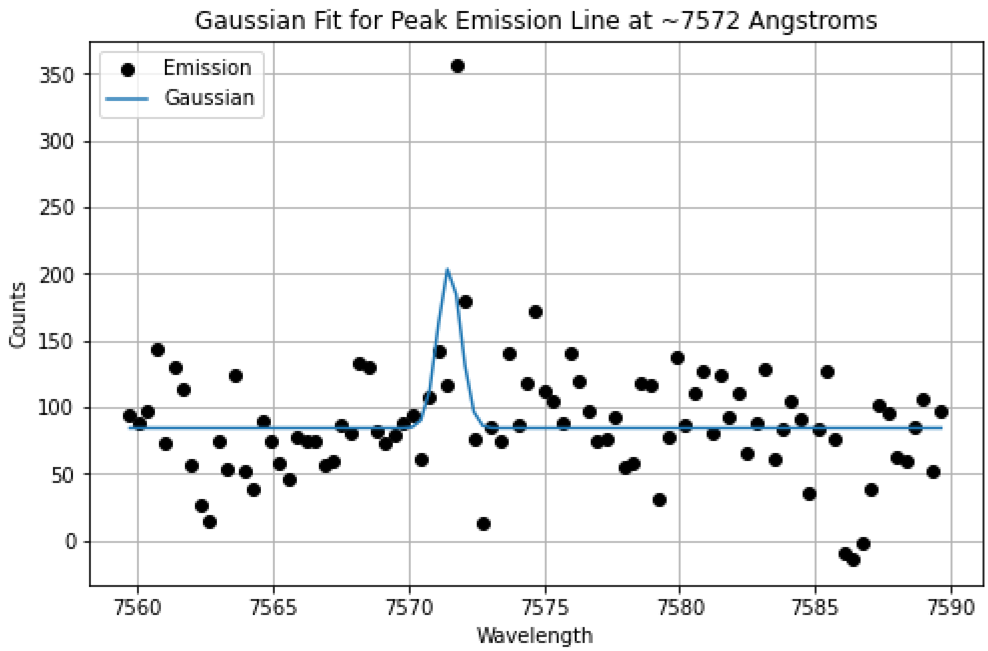
Before fitting a Gaussian to each of these three emission lines, I first wrote the following block of code to correspond the pixel number to the specified wavelength. To do this, I first subtracted a value of 6328 from each wavelength, then spliced the spectrum according to the new values.

```
peak1 = flx2[2662:2754] #7245 - 7275
peak2 = flx2[2862:2955] #7310 - 7340
peak3 = flx2[3634:3727] #7560 - 7590
```

I then fit a Gaussian to each of the emission lines shown above, using each of the peak values as the y-variable for each respective case. I did this using the code that was provided to us in lab 6. The Gaussian fits as well as the emission profiles that they pertain to are shown in the three plots below:


Gaussian Fit for Peak Emission Line at ~7260 Angstroms
Emission
Gaussian
Counts
Wavelength
300
250
200
150
100
50
0
−50
−100
7245
7250
7255
7260
7265
7270


Gaussian Fit for Peak Emission Line at ~7330 Angstroms
Emission
Gaussian
Counts
Wavelength
500
400
300
200
100
0
−100
7310
7315
7320
7325
7330
7335
7340



Below is a table that compares the fitted parameters for each of the lines on the plots above:

Line	C	A	Wavelength	σ	Emission	Redshift
Line 1	88.59	164.5	7260	1.327	H-Beta	0.493
Line 2	79.34	398.4	7330	1.346	O-III	0.478
Line 3	84.38	120.6	7572	0.424	O-III	0.512

It is clear in this table that the three measured redshifts are all within 0.04 units of each other. The redshifts are all extremely similar and close in value. Lines 1 and 2 have especially similar redshifts, and line 3 has a slightly higher value for redshift. Considering the velocity of the object emitting this spectrum, this corresponds to a velocity spread of 9E6 Meters/Second (using generic redshift formula). The width of the peak at 7572 Angstroms seems to be narrower than the other two widths.

Using the fitted central wavelengths for the three emission lines, and making the assumption that the three features correspond to Hβ and [OIII], I measured the redshifts of the objects as determined by the fit to each line. Using this data that I found, I created the following table with three redshift values and the wavelengths they correspond to:

Variable	Measurement (Angstroms)	Value it Corresponds To
Hβ	4861	7269 Angstrom Peak
[OIII]	4959	7330 Angstrom Peak
[OIII]	5007	7572 Angstrom Peak

As you can see in the table above, the [OIII] lines are of similar but not equal strengths. The peaks correspond well with the expected 1:3 ratio. The first [OIII] peak is about 3 times the value of the second [OIII] peak.