LAB-2-CODE

November 16, 2020

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0.1.1 Lab 2 Code

0.1.2 Functions

```python
[63]: import matplotlib.pyplot as plt
      import numpy as np
      import astropy.io.fits as fits

      def plotspectrum(name):
          filename = name
          data = np.genfromtxt(filename, skip_header = 17, skip_footer=1)
          pos = data[:,0]
          intensity = data[:,1]
          %matplotlib inline
          plt.figure(1)
          plt.plot(pos, intensity, 'o-', markersize = 2)
          plt.xlabel("Pixel Position")
          plt.ylabel("Intensity")
          plt.show()

      def centroid_finder(x,y,bias): #Take the x and y values of the spectrum.
          s = []
          I = []
          cmean = []
          cstddev = []
          i = 0
          while i < len(x): #Goes through all of the pixels
              if y[i] > bias: #Skip over any pixel lower than the noise
                  check = True
              else:
                  check = False
              if check:
                  s.append(x[i])
                  I.append(y[i])
                  if y[i-1] >= y[i] and y[i] < y[i + 1] or y[i + 1] <= bias:
                      #If new emission line is found, find standard deviation and␣
      ↪mean and append it
```

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```python
                m = np.sum((np.multiply(s,I)) / np.sum(I))
                cmean.append(m)
                #standard deviations
                std = np.sum(np.multiply(I,(s-m)**2)) / np.sum(I)
                cstddev.append(std)
                #Clear the arrays
                s = []
                I = []
        i += 1 #if there are more pixels, check again.
    return [cmean,cstddev] #return the arrays of centroids and standard
 ↪deviations as a new array


def linfit(x,y):
    a = np.array([[np.sum(np.power(x,2)),np.sum(x)],[np.sum(x),x.size]])
    b = np.array([[np.sum(np.multiply(x,y))],[np.sum(y)]])
    c = np.matmul(np.linalg.inv(a),b)
    return c


def linfit_error(x,y,m,c):
    N = x.size
    sig2 = 1/(N-2)*(np.sum(np.power(y-(m*x+c),2)))
    sign2=N*sig2/(N*np.sum(np.power(x,2))-np.power(np.sum(x),2))
    sigc2 = sig2*np.sum(np.power(x,2))/(N*np.sum(np.power(x,2))-np.power(np.
 ↪sum(x),2))
    return [np.sqrt(sign2),np.sqrt(sigc2)]


def reduce(science,flat,bias):
    bias = np.array(bias)/1.00001
    flat = np.array(flat)
    science = np.array(science)
    flat_norm = (flat-bias/np.median(flat-bias))
    science_reduced = science-bias/flat_norm
    return science_reduced
```
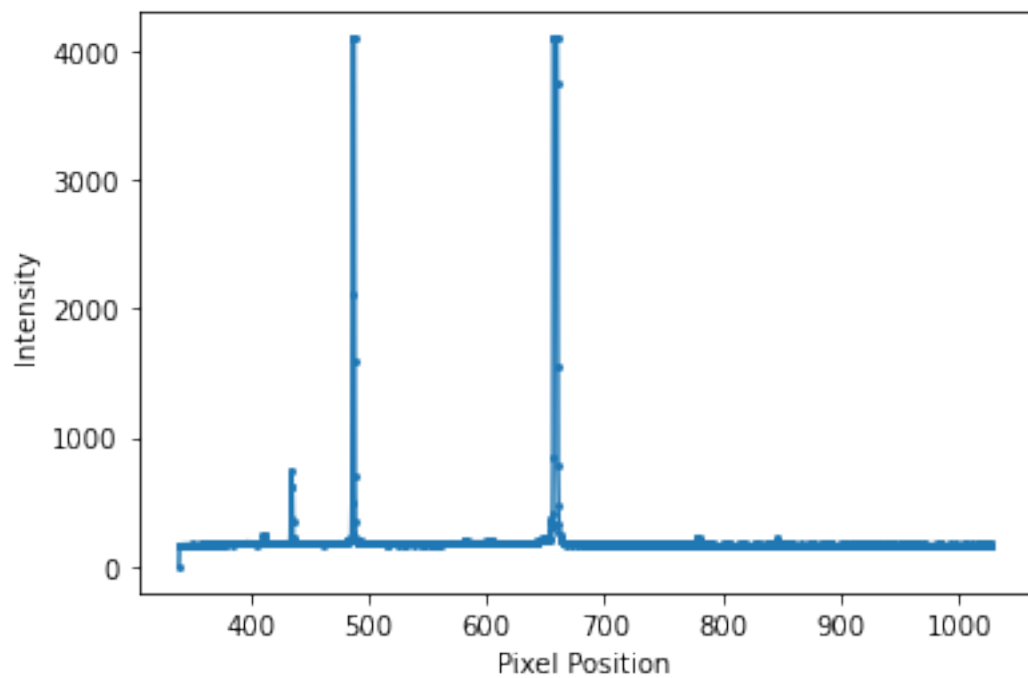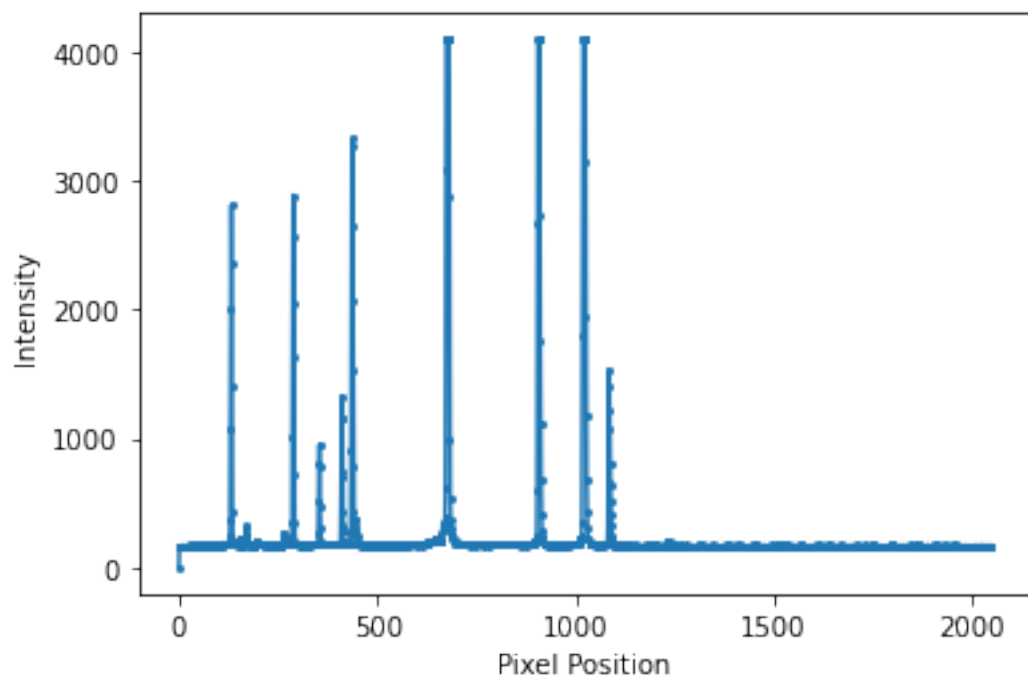
```python
[64]: filenames = ["Hydrogen01870.txt", "groupc-Helium02190.txt",
 ↪"groupc-mercury01590.txt",
                "groupc-neon01250.txt", "groupc-lamp01690.txt", ]
i = 0
while i<len(filenames):
    %matplotlib inline
    print("Data:", filenames[i])
    plotspectrum(filenames[i])
    i+=1
```
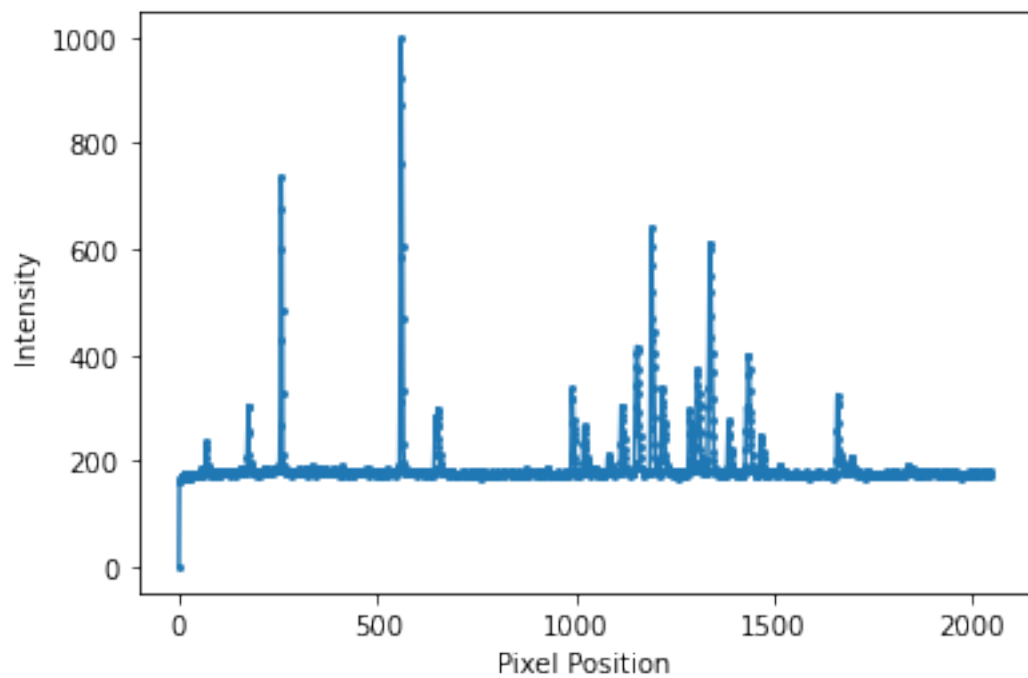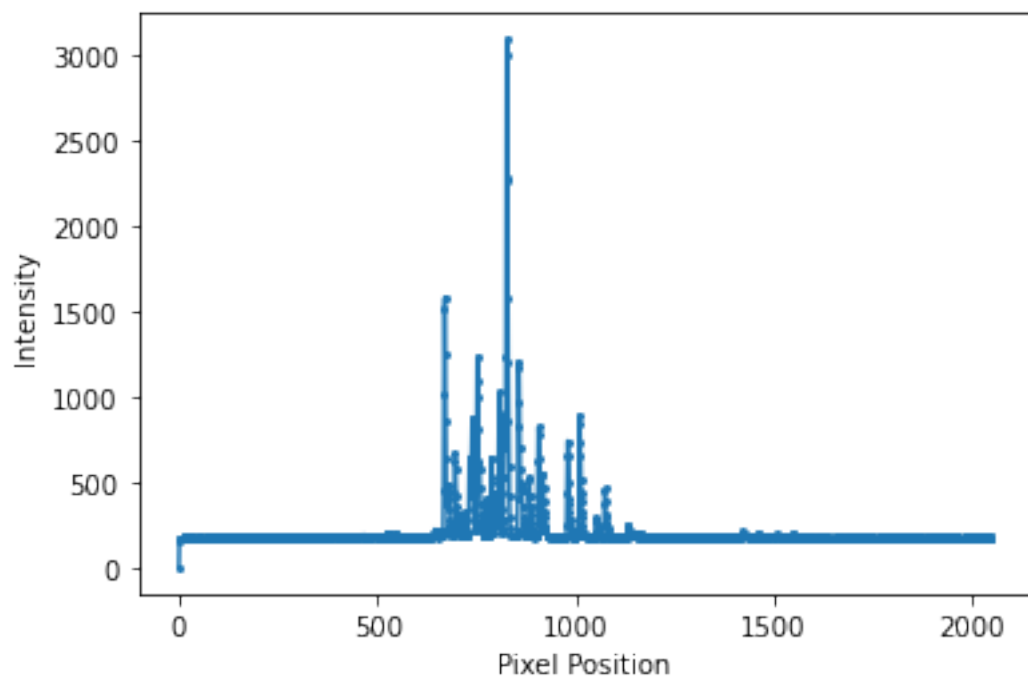
```
Data: Hydrogen01870.txt
```
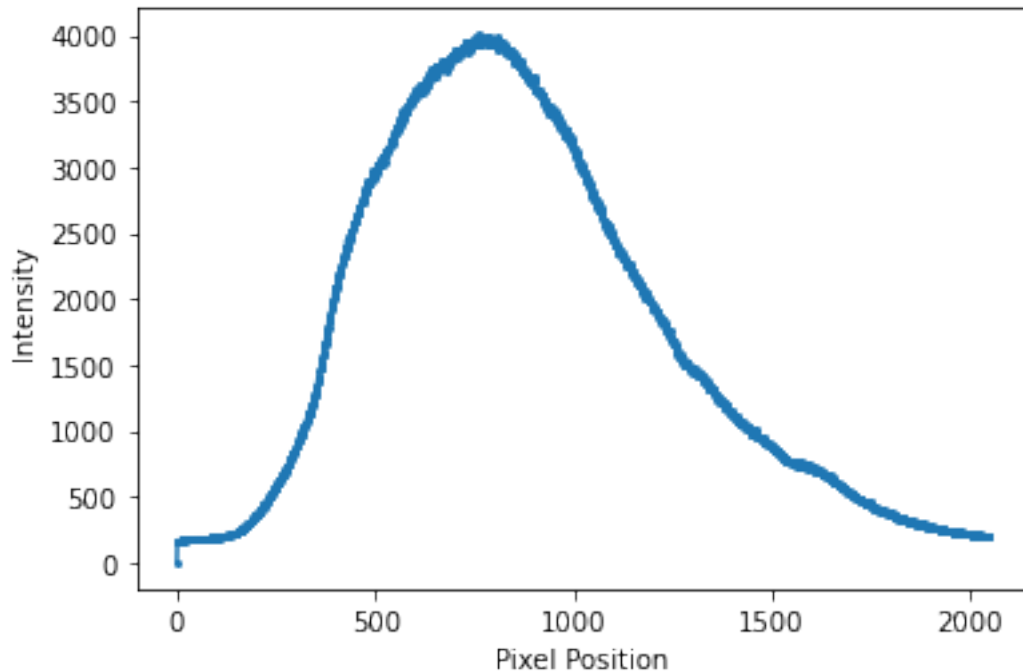
Data: groupc-Helium02190.txt

Data: groupc-mercury01590.txt

3

Data: groupc-neon01250.txt

Data: groupc-lamp01690.txt

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0.1.3 Finding Centroids

```
[65]: i = 0
      centroiddata = []
      centroidstds = []
      while i < len(filenames):
          data = np.genfromtxt(filenames[i], skip_header = 17, skip_footer = 1)
          pos = data[:,0]
          intensity = data[:,1]
          c = centroid_finder(pos, intensity, 220)
          print("file :", filenames[i])
          print(c)
          centroiddata.append(c[0])
          centroidstds.append(c[1])
          i += 1
```

```
file : Hydrogen01870.txt
[[411.1832692307692, 435.0827676322418, 487.36251279960135, 647.99,
654.266424352567, 658.3329715310178, 778.7347128129602], [0.09195277366863903,
0.36206082257952765, 0.4666769172277576, 0.0, 0.4305876236504802,
1.6206449867478276, 0.06923257584465954]]
file : groupc-Helium02190.txt
[[132.02232393050625, 152.495670995671, 168.9281609195402, 265.96989528795814,
288.3707544723879, 353.9975686846584, 411.2439817826936, 436.98832182721463,
445.4630620985011, 646.4967320261437, 665.1218103033221, 677.7912118217544,
```

907.6634926741687, 1010.4956140350878, 1012.0, 1021.7811942277293,
1085.5953213817227], [2.373964560116664, 0.24998125972151944,
1.7879425947945566, 0.6496172665222992, 2.489107537244495, 2.61657565933542,
3.120043481776133, 3.4342142235451223, 2.549492122482106, 0.24998932034687515,
3.617805485440303, 13.227315041496539, 7.368087560773174, 0.2499807633117882,
0.0, 10.166391536953068, 7.282890222468051]]
file : groupc-mercury01590.txt
[[69.48913043478261, 174.50987432675043, 258.10568181818184, 561.0188834154351,
646.9955290611028, 652.8651088688264, 992.7629805786762, 1022.4069286452947,
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1386.8745684695052, 1430.1136531365314, 1437.5515850144093, 1466.5,
1660.848094747683], [0.24988185255198486, 1.1619312229854086, 2.904740444214876,
5.464175436325937, 1.9299353013164062, 3.791682237218211, 6.359200311553055,
5.103798943202198, 7.812250305926228, 13.832500182108694, 11.210298397050535,
3.697219043718218, 0.66827948925959, 7.910268790649448, 10.503625938476285,
14.340078653592167, 3.8922070922624443, 1.8778578723056605, 9.09748307850742,
1.227035490605428, 3.656121498746873]]
file : groupc-neon01250.txt
[[645.0, 670.6976389052038, 679.8787765759046, 696.9963768115942,
705.3634161114476, 720.4439083232811, 732.6447412353924, 739.9567754878715,
754.7526240194453, 774.28095818108, 788.857177380377, 799.3304640718563,
808.1852329517975, 820.8760577401692, 827.6161117961366, 857.6080224155729,
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1131.9761570827488], [0.0, 5.430250504169458, 5.001716668097339,
6.302160785549254, 2.78494871782643, 2.675080503054969, 2.318532445561746,
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6.59050300901786, 7.4718607848097625, 9.990780473994235, 1.9134883900084096,
7.065294618576615, 0.6600205756055149]]
file : groupc-lamp01690.txt
[[140.0, 142.98958333333334, 147.9926793557833, 150.49780701754386,
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```

0.1.4 Wavelength Calibration

(Wavelength vs Pixel Centroid Plots)

```python
[66]: # Wavelengths taken from the webpage recommended by professor
      # Direct Link: https://physics.nist.gov/PhysRefData/ASD/lines_form.html


      #Chosen Wavelengths
      H_chosen_WL = np.array([410.1734, 434.0472, 486.135, 656.279])

      HE_chosen_WL = np.array([257.76, 388.8648, 402.61914, 447.14802, 706.5190, 1091.
       ↪292])

      HG_chosen_WL = np.array([82.1329, 167.2537, 249.2064, 567.7105, 952.0198, 1128.
       ↪71])

      NE_chosen_WL = np.array([640.22480, 692.94672, 837.76070, 865.43828, 966.54200,␣
       ↪1117.75246])

      #It is clear that the lamp has a continuous emission spectrum
      #so there is no point in matching wavelengths to centroids for this particular␣
       ↪object


      #Chosen Centroids
      H_chosen_CDS = np.array([411.1832692307692, 435.0827676322418, 487.
       ↪36251279960135, 654.266424352567])

      HE_chosen_CDS = np.array([265.96989528795814, 353.9975686846584, 411.
       ↪2439817826936, 445.4630620985011, 677.7912118217544,
                        1085.5953213817227])

      HG_chosen_CDS = np.array([69.48913043478261, 174.50987432675043, 258.
       ↪10568181818184, 561.0188834154351, 992.7629805786762,
                        1218.9766777724892])

      NE_chosen_CDS = np.array([645.0, 696.9963768115942, 827.6161117961366, 865.
       ↪846017699115, 981.4306358381504, 1131.9761570827488])


      chosenWL = [H_chosen_WL, HE_chosen_WL, HG_chosen_WL, NE_chosen_WL]
      chosenCDS = [H_chosen_CDS, HE_chosen_CDS, HG_chosen_CDS, NE_chosen_CDS]
```

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```
names = ["Hydrogen", "Helium", "Mercury", "Neon"]

i = 0
while i<=3:
    print(names[i],"Fit")
    fit = linfit(chosenWL[i],chosenCDS[i])
    fite = linfit_error(chosenWL[i],chosenCDS[i],fit[0],fit[1])
    print("Slope, Intercept:", np.transpose(fit))
    print("Error:", fite)
    plt.figure()
    %matplotlib inline
    plt.plot(chosenWL[i], chosenCDS[i], 'o-', markersize = 2)
    x = np.array(range(int(np.min(chosenWL[i])),))
    plt.plot(x,fit[0]*x+fit[1],'k',alpha = 0.5)
    plt.xlabel("Centroid (pixel position)")
    plt.ylabel("Wavelength (nm)")
    plt.show()
    i+=1
```
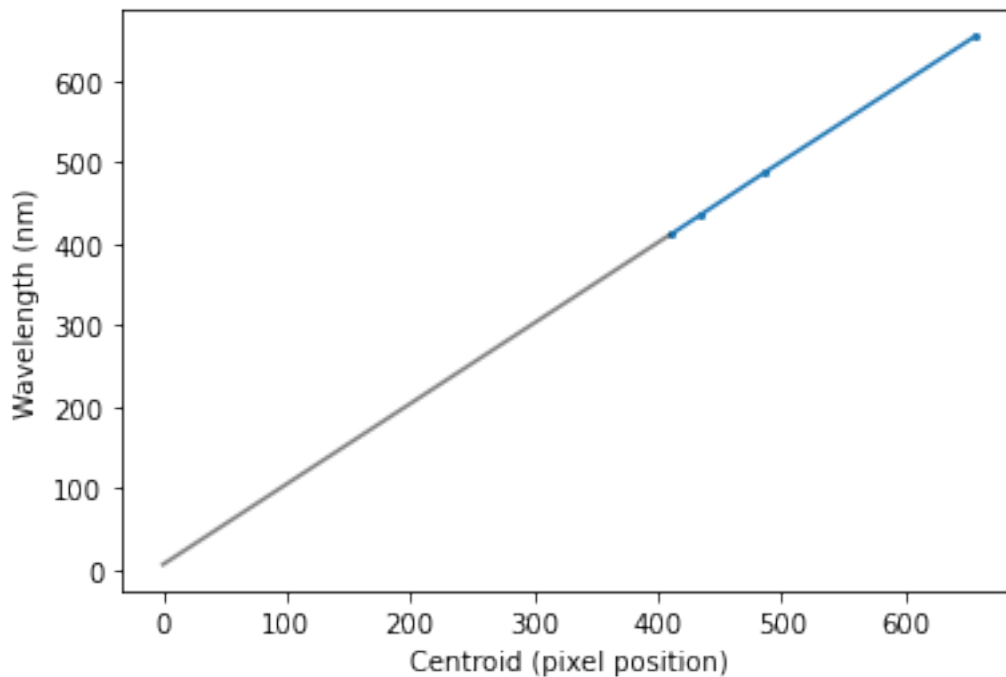
Hydrogen Fit
Slope, Intercept: [[0.98685179 6.84526712]]
Error: [0.003405191250559764, 1.72262677954393]

Helium Fit
Slope, Intercept: [[0.98804948 -2.46241326]]

Error: [0.030031642999770614, 18.471238251233068]
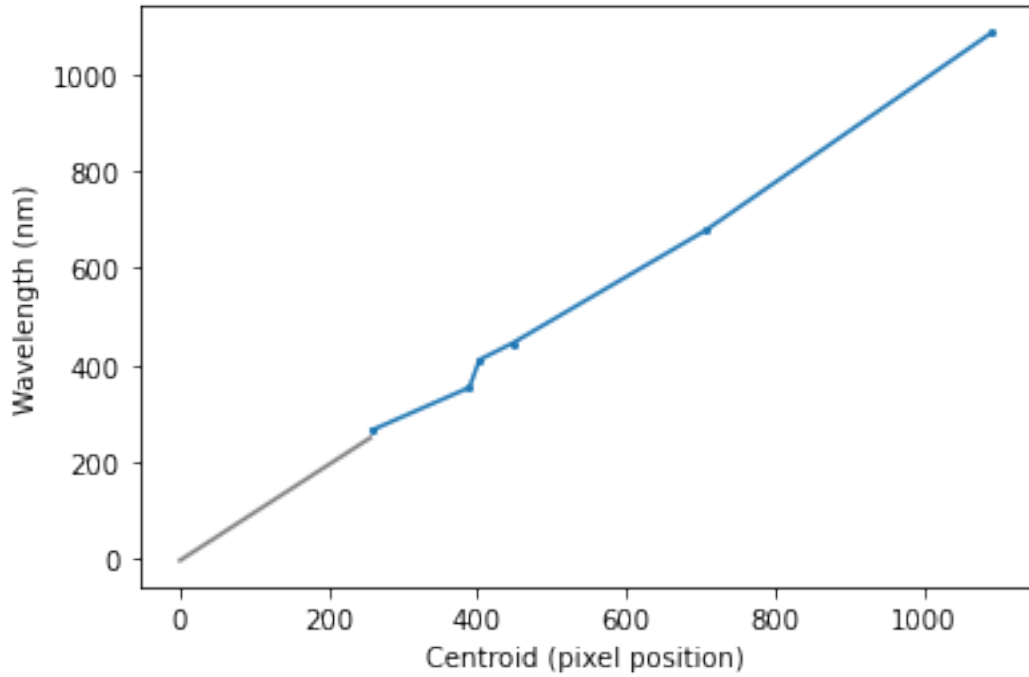
Mercury Fit
Slope, Intercept: [[1.07611609 -18.61832225]]
Error: [0.022516000442013254, 14.820268606972371]
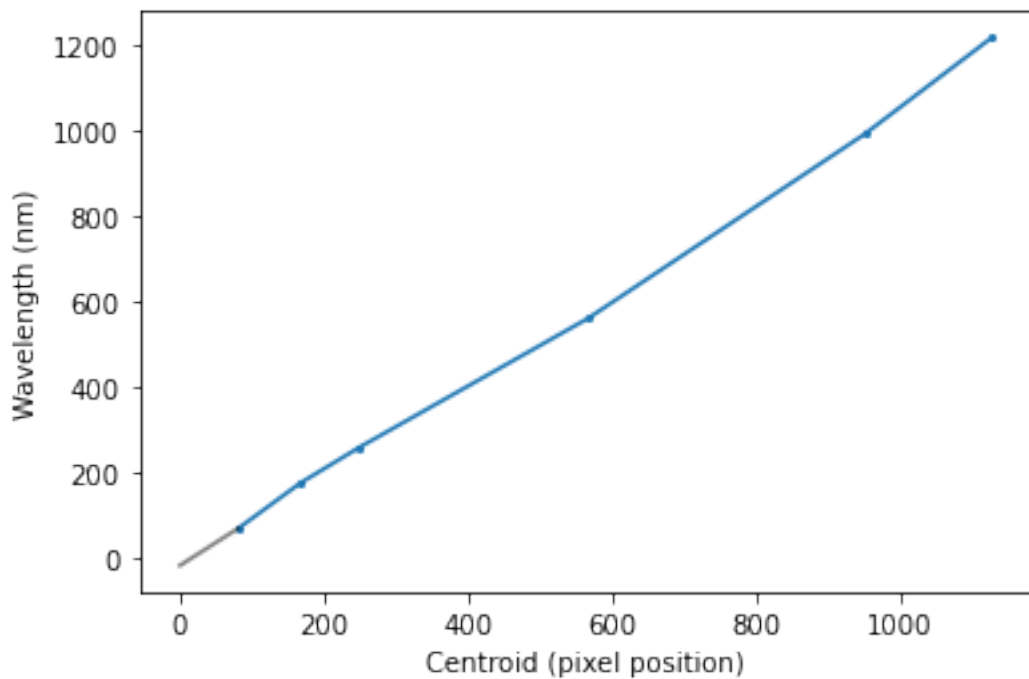
```
Neon Fit
Slope, Intercept: [[  1.0255357   -17.09323737]]
Error: [0.02323538484490006, 20.177055218310354]
```
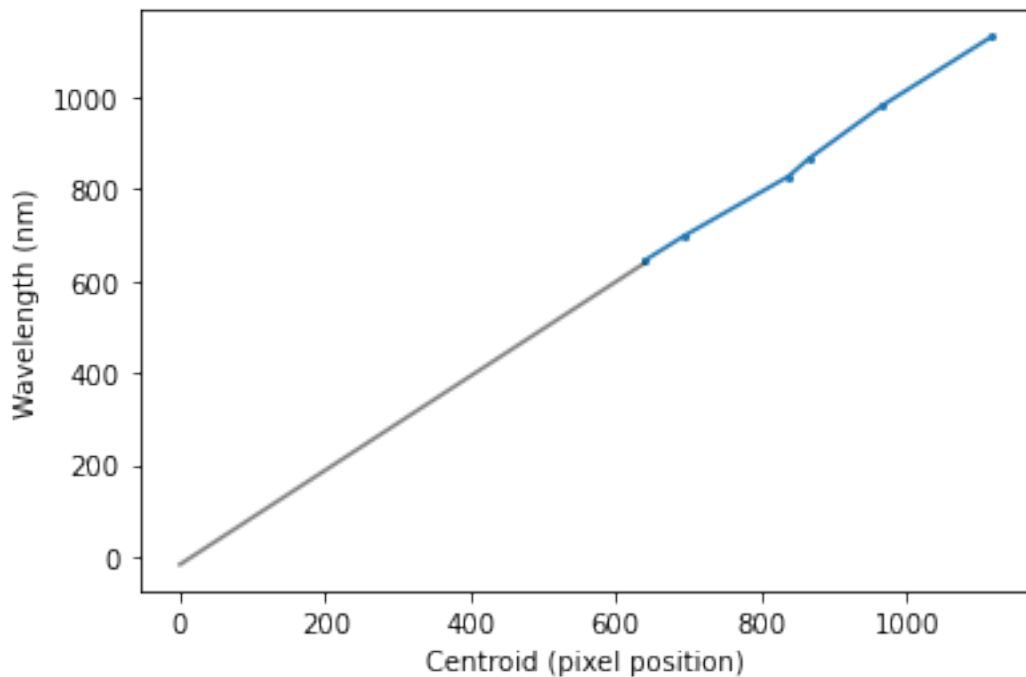

0.1.5 KAST Spectrograph Data Analysis

```
[67]: def reduce(science,flat,bias):
          bias = np.array(bias)/1.00001
          flat = np.array(flat)
          science = np.array(science)
          flat_norm = (flat-bias/np.median(flat-bias))
          science_reduced = (science-bias)/flat_norm
          return science_reduced

      #Will be using these fits files
      #b151 Zw 229-015 Seyfert 1 Galaxy
      #b158 3C079 Seyfert 2 Galaxy

      Galaxy1_name = "data-2013-10-26-shane-public/b151.fits"
      Galaxy2_name = "data-2013-10-26-shane-public/b158.fits"
      Galaxy1 = fits.getdata(Galaxy1_name)
      Galaxy2 = fits.getdata(Galaxy2_name)
```

```python
bias_name = "data-2013-10-26-shane-public/b101.fits"
bias = fits.getdata(bias_name)

domeflat4_name = "data-2013-10-26-shane-public/b112.fits"
domeflat2_name = "data-2013-10-26-shane-public/b121.fits"
dome4s = fits.getdata(domeflat4_name)
dome2s = fits.getdata(domeflat2_name)

w=2020
h=20
rGalaxy1 = reduce(Galaxy1[h:279,0:w],dome4s[h:279,0:w],bias[h:279,0:w])
rGalaxy2 = reduce(Galaxy2[h:279,0:w],dome4s[h:279,0:w],bias[h:279,0:w])
%matplotlib inline

plt.figure()
plt.title("Bias Frame")
plt.imshow(bias[h:279,0:w],origin = 'lower', interpolation = 'nearest', cmap =
 →'pink')

plt.figure()
plt.title("Dome Frame 2s")
plt.imshow(dome2s[h:279,0:w],origin = 'lower', interpolation = 'nearest', cmap
 →= 'pink')

plt.figure()
plt.title("Dome Frame 4s")
plt.imshow(dome4s[h:279,0:w],origin = 'lower', interpolation = 'nearest', cmap
 →= 'pink')

plt.figure()
plt.title("Zw 229-015 Seyfert 1 Galaxy")
plt.imshow(Galaxy1,origin = 'lower', interpolation = 'nearest', cmap = 'pink')

plt.figure()
plt.title("Zw 229-015 Seyfert 1 Galaxy REDUCED")
plt.imshow(rGalaxy1,origin = 'lower', interpolation = 'nearest', cmap = 'pink')

plt.figure()
plt.title("3C079 Seyfert 2 Galaxy")
plt.imshow(Galaxy2,origin = 'lower', interpolation = 'nearest', cmap = 'pink')

plt.figure()
plt.title("3C079 Seyfert 2 Galaxy REDUCED")
plt.imshow(rGalaxy2,origin = 'lower', interpolation = 'nearest', cmap = 'pink')
```
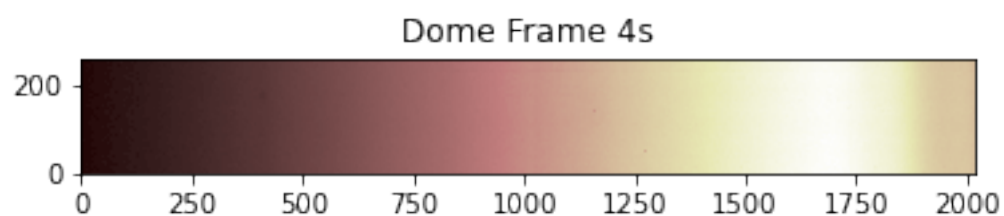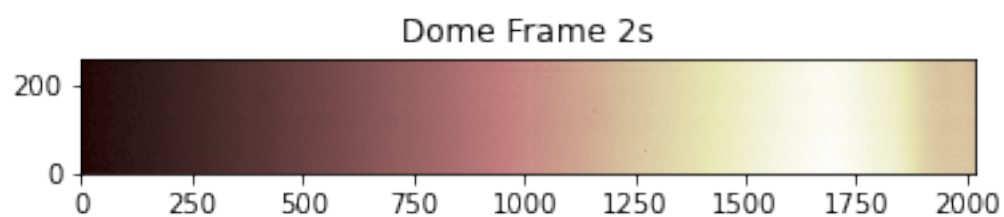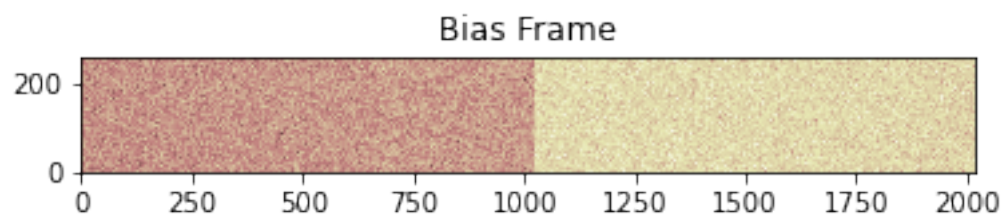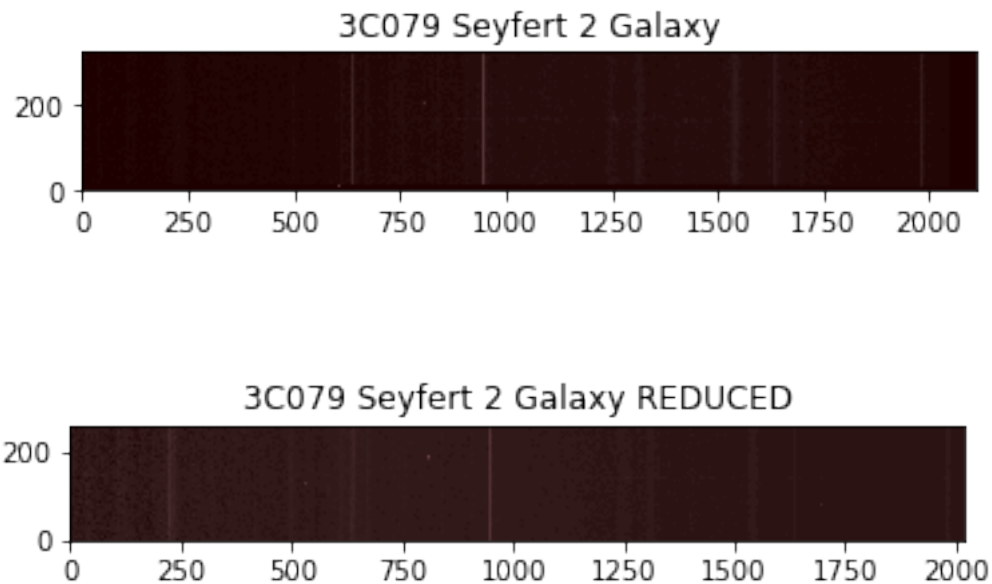
[67]: <matplotlib.image.AxesImage at 0x7f0349bbcb50>

Bias Frame

Dome Frame 2s

Dome Frame 4s

Zw 229-015 Seyfert 1 Galaxy

Zw 229-015 Seyfert 1 Galaxy REDUCED

3C079 Seyfert 2 Galaxy

3C079 Seyfert 2 Galaxy REDUCED
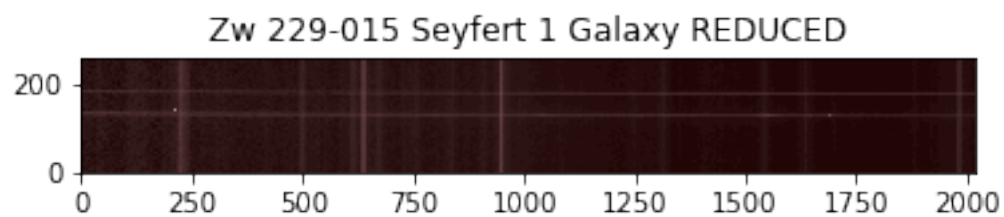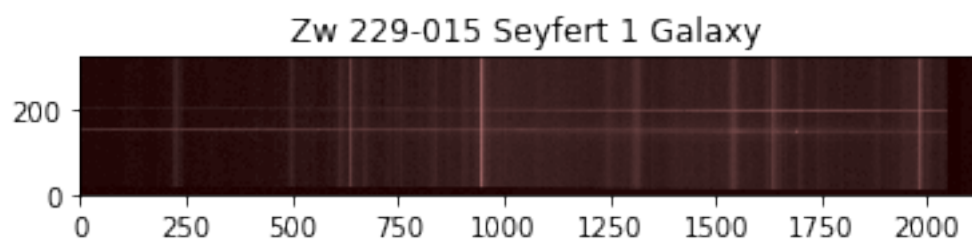
```
[68]:  def linearize(science,max1,max2):
           i = 0
           size = science[0].size
           spectrum = []
           m = (max2-max1)/-size
           while i<size:
               spectrum.append(science[int(max1-m*i),i])

               i+=1
           return np.array(spectrum)

       %matplotlib inline
       s1 = linearize(Galaxy1[h:279,0:w]-(bias[h:279,0:w]/1.000001),177,166)
       plt.figure()
       x = np.array(range(0,2020))
       plt.plot(x, s1, 'o-', markersize = 2)
       plt.xlabel("Pixel Position")
       plt.ylabel("Intensity")
       plt.show()

       s2 = linearize(Galaxy2[h:239,0:w]-(bias[h:239,0:w]/1.000001),177,166)
       plt.figure()
       x = np.array(range(0,2020))
       plt.plot(x, s2, 'o-', markersize = 2)
       plt.xlabel("Pixel Position")
```

```
plt.ylabel("Intensity")
plt.show()
```


20
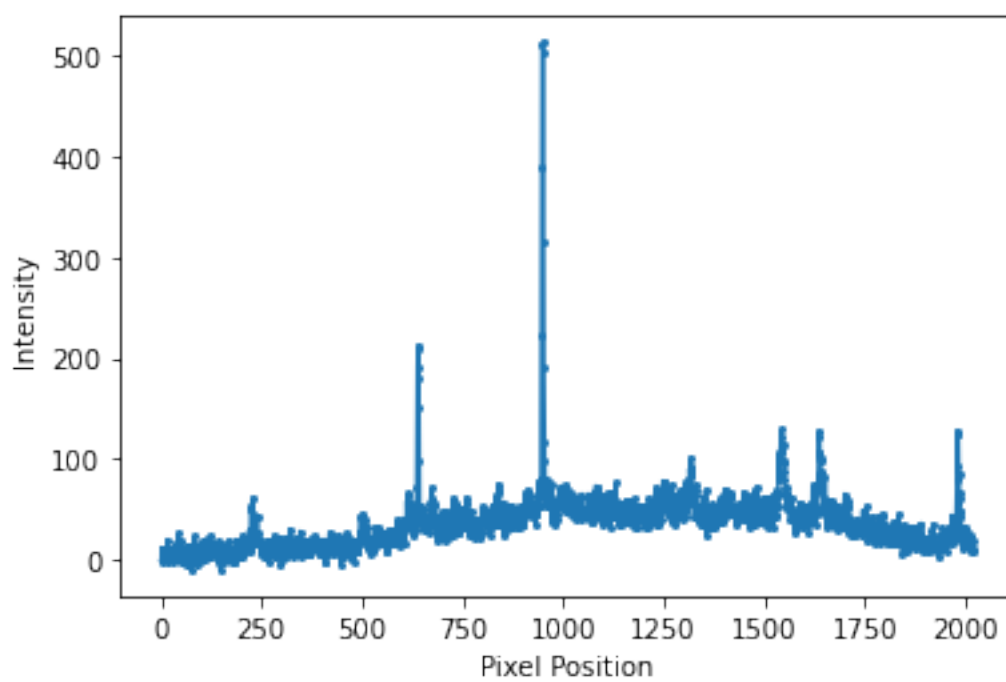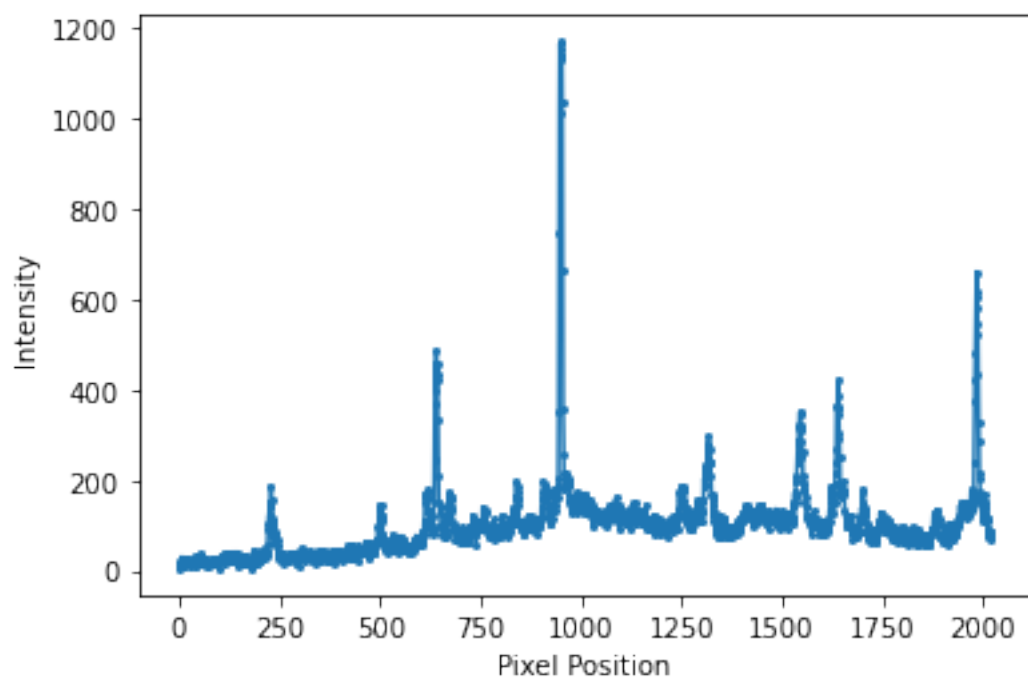
```python
[69]:  #Need to make this based on wavelength rather than pixe position, so we analyze
       →the arc frame.

       arc_name = "data-2013-10-26-shane-public/b100.fits"

       arc = fits.getdata(arc_name)-(bias/1.0000001)
       %matplotlib inline
       plt.figure()
       plt.imshow(arc, origin = 'lower', interpolation = 'nearest', cmap = 'magma')

       larc = linearize(arc[h:279,0:w] - (bias[h:279,0:w]/1.000001),177,166)
       plt.figure()
       x = np.array(range(0,2020))
       arc_centroids = centroid_finder(x, larc, 1000)
       plt.plot(x, larc[0:2020], 'o-', markersize = 2)
       plt.plot(arc_centroids, np.full(len(arc_centroids),40000), 'o', markersize = 2)
       plt.xlabel("Pixel Position")
       plt.ylabel("Intensity")
       plt.show()

       print(arc_centroids)
```
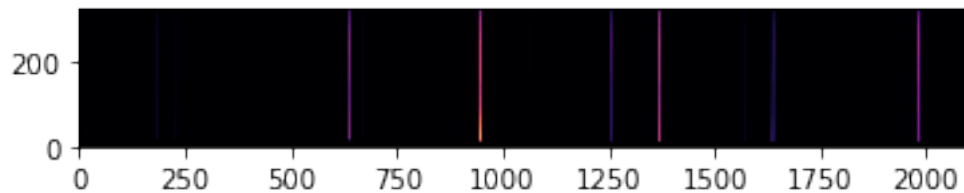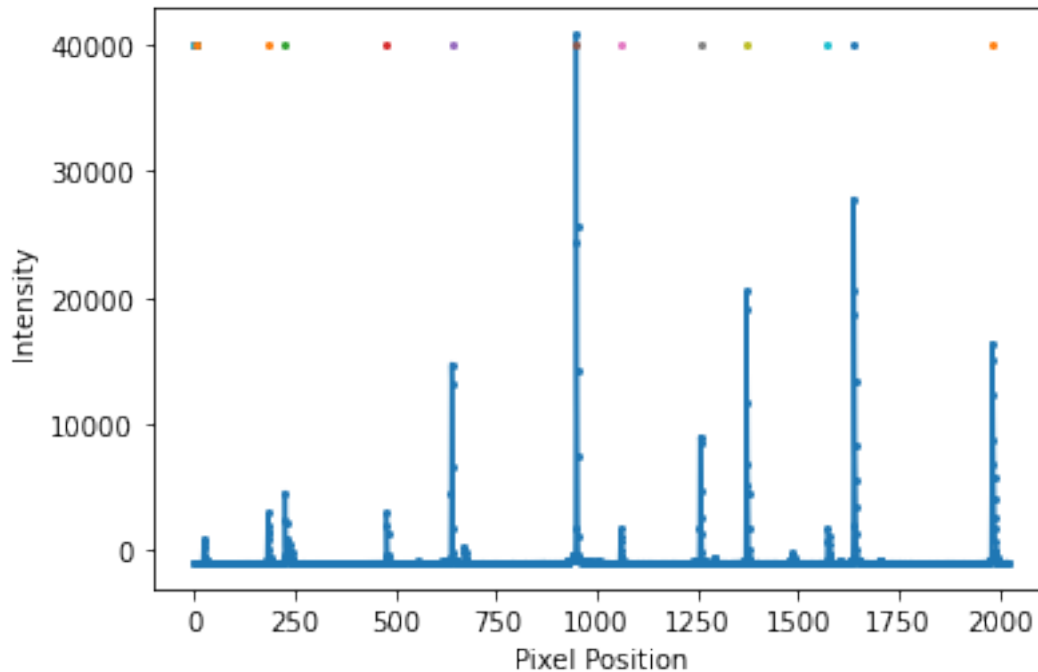
[[183.47805332091258, 225.96198348537462, 477.91213193039266, 639.6690633819476, 949.4593420876913, 1058.6120116976404, 1257.0549606202846, 1372.2137341691166, 1573.3783178601757, 1638.9538631929363, 1982.7861040086375], [0.9913299290853752, 0.4956346976331415, 0.524769672227625, 1.023459406504145, 1.5025611901714209, 0.23745337959171756, 1.5357297773385163, 2.0759824927928427, 0.23519345684777784, 2.998893167204087, 3.90562882050507]]

```
[70]: Ref_WL = np.array([326.1, 340.3, 361.05, 388.86, 404.66, 435.33, 447.15, 467.
      →82, 479.99, 508.58, 546.74])

      arc_centroids = np.array(arc_centroids[0])

      calibrate = linfit(arc_centroids, Ref_WL)
      calibrate_error = linfit_error(arc_centroids, Ref_WL, calibrate[0],␣
      →calibrate[1])
      cm = float(calibrate[0])
      ci = float(calibrate[1])
      print("Slope/Intercept:", np.transpose(calibrate))
      print("Error:", calibrate_error)

      %matplotlib inline
      plt.figure()
      plt.plot(Ref_WL, arc_centroids, 'o-', markersize = 2)
      x = np.array(range(int(np.min(Ref_WL),)))
      plt.plot(x, calibrate[0]*x + calibrate[1], 'k', alpha = 0.5)
```
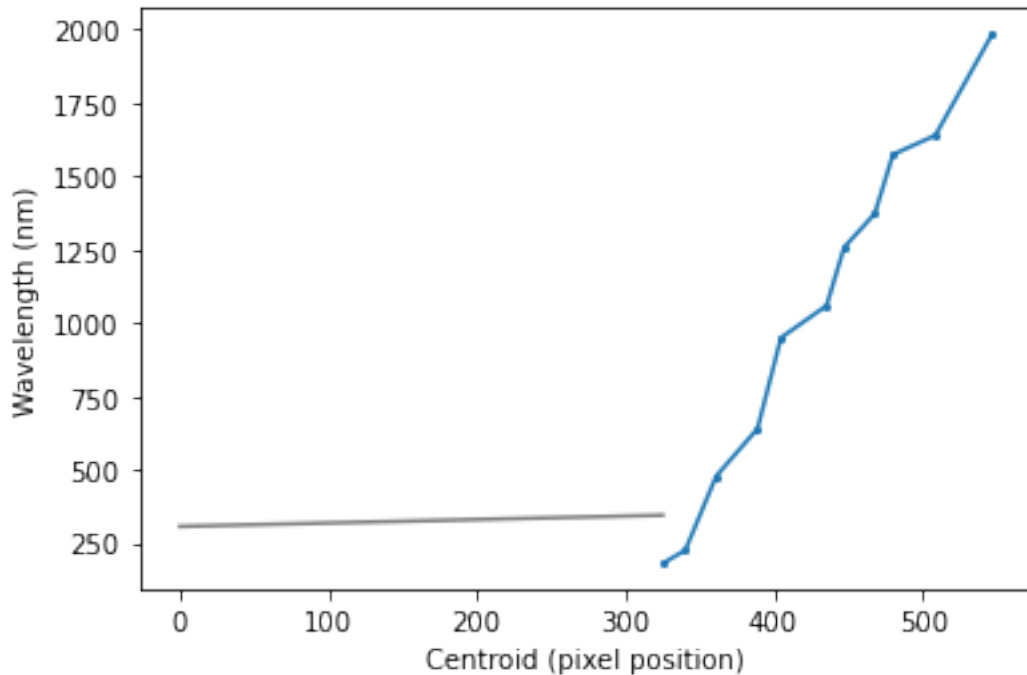
```
plt.xlabel("Centroid (pixel position)")
plt.ylabel("Wavelength (nm)")
plt.show()
```

Slope/Intercept: [[1.17516819e-01 3.06513645e+02]]
Error: [0.004436790175269142, 5.23273178673198]
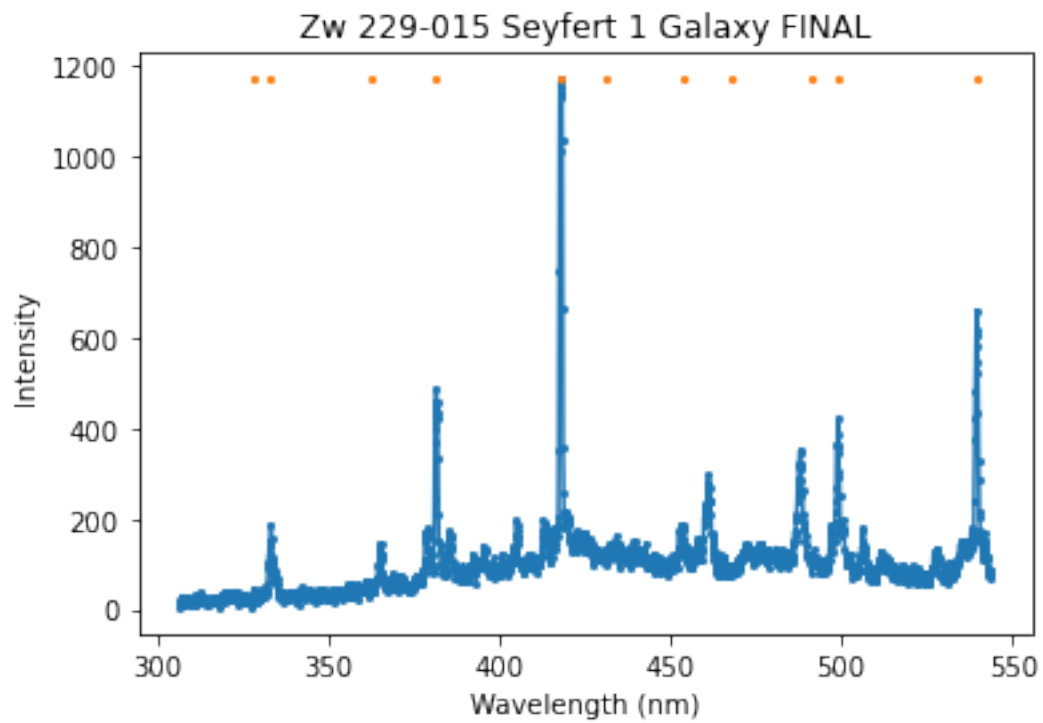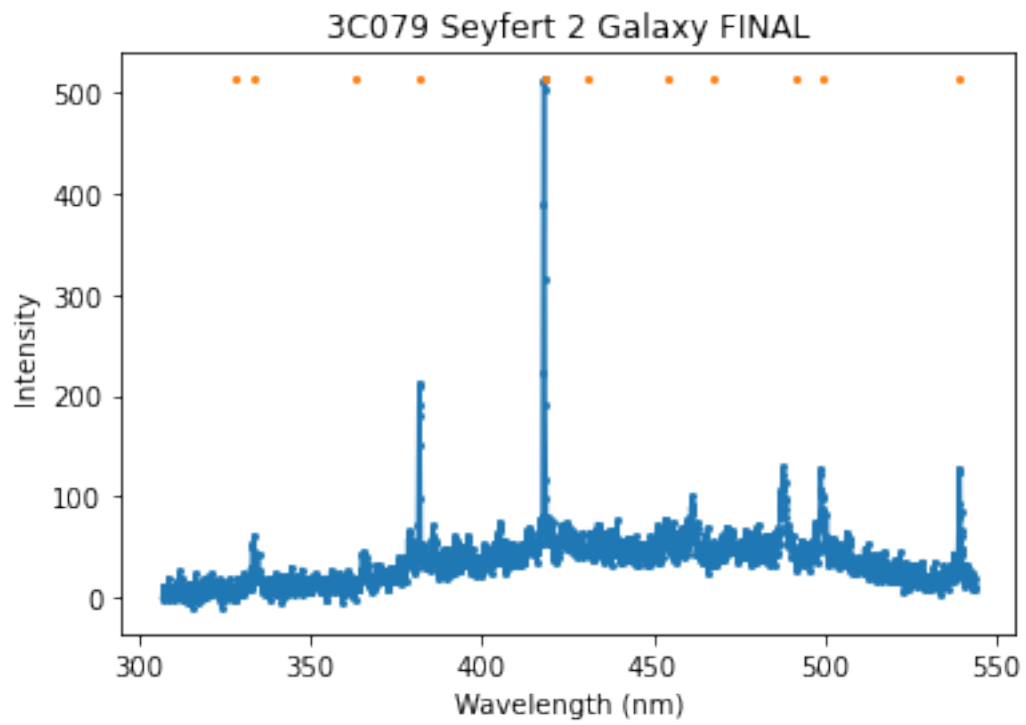


```
[71]: %matplotlib inline
      x = np.array(range(0,2020))
      plt.figure()
      plt.plot(x*cm + ci, s1, 'o-', markersize = 2)
      plt.plot(arc_centroids*cm + ci, np.full(len(arc_centroids),np.max(s1)), 'o',␣
       ↪markersize = 2)
      plt.title("Zw 229-015 Seyfert 1 Galaxy FINAL")
      plt.xlabel("Wavelength (nm)")
      plt.ylabel("Intensity")
      plt.show


      plt.figure()
      plt.plot(x*cm + ci, s2, 'o-', markersize = 2)
      plt.plot(arc_centroids*cm + ci, np.full(len(arc_centroids),np.max(s2)), 'o',␣
       ↪markersize = 2)
      plt.title("3C079 Seyfert 2 Galaxy FINAL")
      plt.xlabel("Wavelength (nm)")
```

```
plt.ylabel("Intensity")
plt.show
```

[71]: `<function matplotlib.pyplot.show(*args, **kw)>`

3C079 Seyfert 2 Galaxy FINAL

[ ]: