Assignment 3 - Data Estimation

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1 Introduction

The assignment aims to estimate various physical parameters from the dataset provided which is about spectral radiance per unit wavelength. We are provided with four datasets with wavelength and corresponding spectral radiance and each with varying noise and number of data points. Our goal here is to estimate various parameters by fitting a curve to this data.

The equation for spectral radiance per unit wavelength is given by

$$B_\lambda(\lambda, T) = \frac{2hc^2}{\lambda^5} \frac{1}{e^{\frac{h\nu}{k_B T}} - 1} \tag{1}$$

1.1 Plotting the given datasets

Data is given in the form of four text files d1.txt, d2.txt, d3.txt and d4.txt. The function `data` takes the name of the text file as input and returns arrays of x and y values. On plotting all 4 of them , the following can be inferred:

- d1 has few data points
- d2 and d4 have too much noise
- d3 seems to be having both ie. a good number of data points and also considerable amount of noise which makes it apt for estimation of parameters compared to the others.

2 Curve Fitting

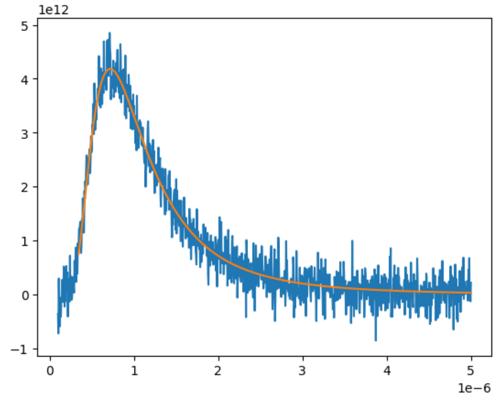
The function `spectral_radiance` takes the parameters wavelength, T, h, c, Kb and returns the value of the function. The function `scipy.optimize.curve_fit` is used to fit the curve with various datasets provided and it gives you the parameters of the best fit curve for the given dataset. Since d3 was the best dataset which we had realised after plotting each of them, we will be fitting curve on d3 dataset by fixing some parameters and varying the other.

This is done by defining a function `newFun` which takes the unknown parameters as the input and returns the value of the spectral radiance function.

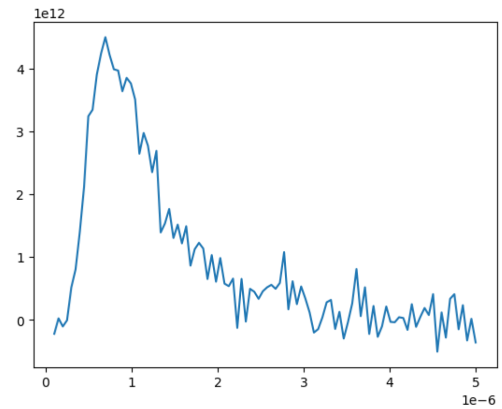
Now Lets start analysing by first keeping all the parameters unknown:

2.1 All Parameters Unknown

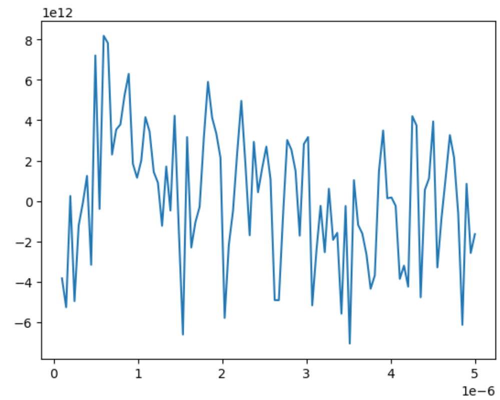
Providing random initial conditions to the curve_fit conditions might result in overflow at times. `RuntimeWarning: overflow encountered in exp` shows up in such cases. To avoid this it is necessary to give suitable initial conditions as input to the function. This is done by calling `curve_fit` with different initial conditions each time. Then the parameter values returned by the `curve_fit` function is used to plot the fitted curve alongside the set of given data points. Although the fitted curves look good, the values are very bad, as expected ehich can be observed from the jupyter notebook.



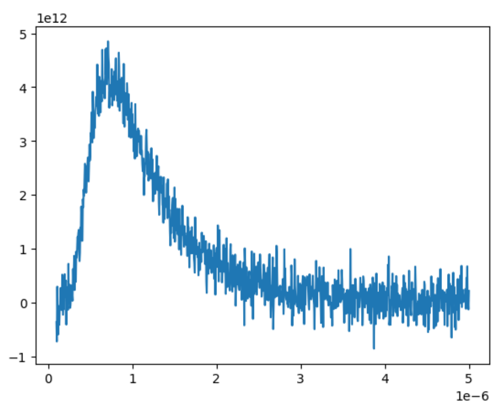
(a) Curve fit keeping all parameters as variable for d3.txt



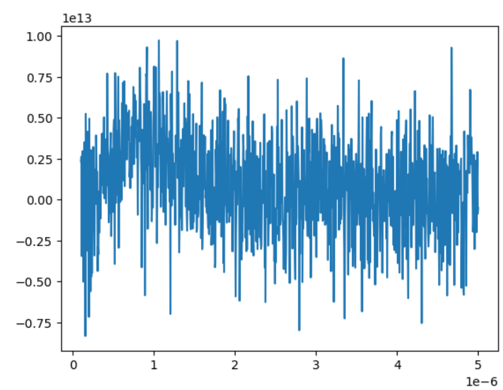
(b) Plot of the dataset d1.txt



(c) Plot of the dataset d2.txt



(d) Plot of the dataset d3.txt



(e) Plot of the dataset d4.txt

Figure 1: Plots of the given datasets

2.2 Partial Application

Now we try fixing certain parameters and varying one parameter at a time and analyse the results. `newFun` takes the variable parameters as input and returns the value of the spectral radiance function after fixing the other parameters.

2.2.1 T as a Variable

Here the temperature (T) is variable and practically this case makes sense since we know the value of all the other constants except the Temperature T. We create a new function `newFun`, a wrapper around `spectral_radiance`. After curve fitting with `d3.txt`, we get the temperature $T = 4010.75$ K.

2.2.2 c as a Variable

Here the speed of light (c) is variable and practically this case makes sense since we know the value of all the other constants except the speed of light c. We use the T obtained from `d3.txt`, $T = 4010.75$ K and we perform curve fitting to find c. The resultant value of c is pretty much accurate when the curve is fitted over d3.txt.

2.2.3 h as a Variable

We utilize the T and c values obtained from `d3.txt` to calculate h. The calculations for h yield accurate results when applied to `d3.txt`, but the accuracy declines when using `d1.txt`, `d2.txt`, and `d4.txt`, which was expected.

2.2.4 Kb as a Variable

Finally, we use all the values obtained from fitting `d3.txt` to estimate k. We get $k = 1.38 \times 10^{-23}$ for `d3.txt`. Below is the table which shows the details of the parameters which were fixed and the parameters obtained from the `curve_fit` function.

T	h	c	k	Variable Parameters value
variable	6.64×10^{-34}	3×10^8	1.38×10^{-23}	[4005.92752892]
4005.93	variable	3×10^8	1.38×10^{-23}	[3.00211201e+08]
4005.93	6.64×10^{-34}	variable	1.38×10^{-23}	[6.63756436e-34]
4005.93	6.64×10^{-34}	3×10^8	variable	[1.37834415e-23]

Table 1: deatils of the curvefit of the dataset d3.txt

3 Results

Although not fixing values for any parameters can lead to a fairly good fit, the results are quite . Using the dataset with the highest number of data points and minimal noise generally yields more accurate outcomes. Additionally, holding one value as unknown at a time tends to produce the best results.