Lab #4: Data Reduction

Kaimi Kahihikolo Due: 17 October 2017

Introduction

Recall that Wien's displacement law is given as,

$$\lambda_{max} = \frac{b}{T}$$

where b is *Wien's displacement constant*, $b = 2.89 \times 10^6$ $[nm \cdot K]$, λ_{max} is the wavelength at which the flux is maximum, and T is temperature of the source. Given the spectra of an object, one can determined the temperature using Eq. 1 by determining λ_{max}. However this is not as simple as determining the location of the absolute maximum flux value in a given spectra—as the flux can be influenced by instrumental and other intrinsic errors. After conducting the standard data reduction steps, fitting the spectra with a function will allow for a more accurate result for the local maximum.

Further recall that the flux, F, is related to temperature by the Stefan-Boltzmann law,

$$F = \sigma T^4$$

where σ is *Stefan-Boltzmann constant*. Therefore, by fitting a fourth degree polynomial to the black body spectra of a source, one can more accurately determine λ_{max}.

Methodology

All of the data analyses are handled in *Python 2.7*, which includes data processing, reduction, and calculations. A quick overview of the analysis,

Outline of Analysis

1. Using the given quartz calibration information, the flat field image is calculated (see Appendix, Fig. 3).
2. Given the raw spectra of the object, the "bias" is approximated by the minimum flux value in spectra.
3. Subtracting the raw spectra by the bias, and further dividing by the flat field image, results in the calibrated spectra of the source.
4. A fourth degree polynomial is then fit to the spectra—barring any infrared red excess. The location of the maximum is then used to calculate the temperature—as discussed in the Introduction.

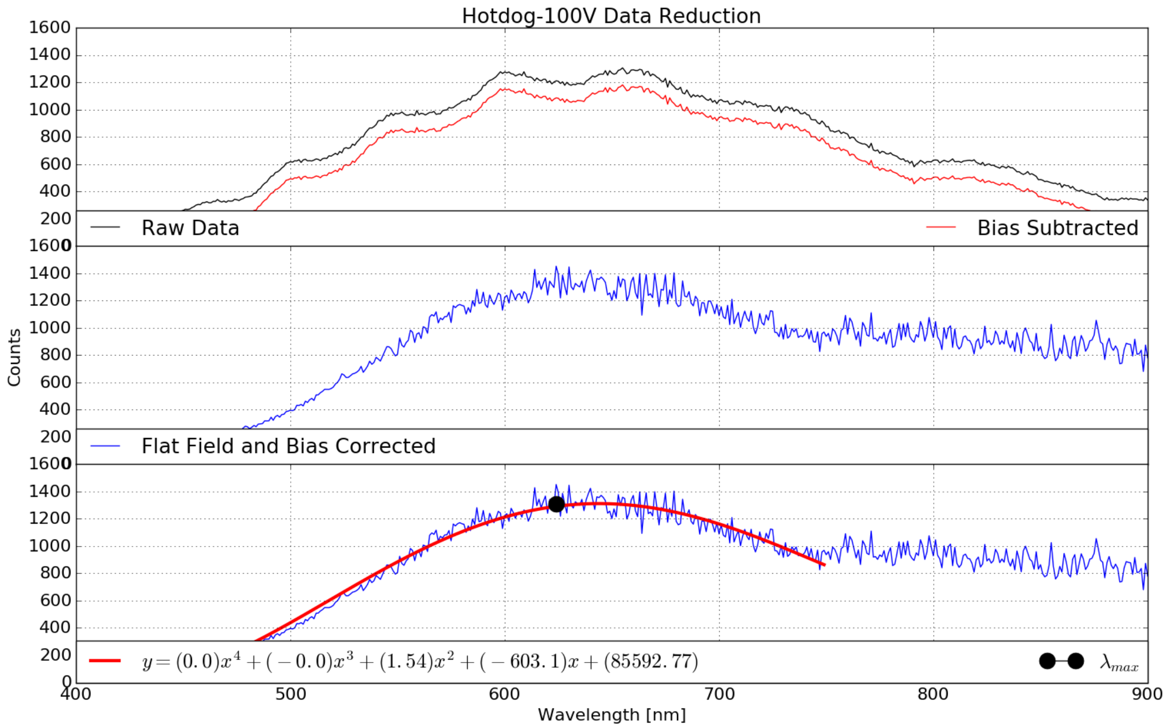

Figure 1: Data Reduction and Analyses of Hotdog-100V. (top) Bias subtracted; (middle) Bias and flat corrected; (bottom) 4th degree fit with noted $\lambda_{max} = 644$ [nm].

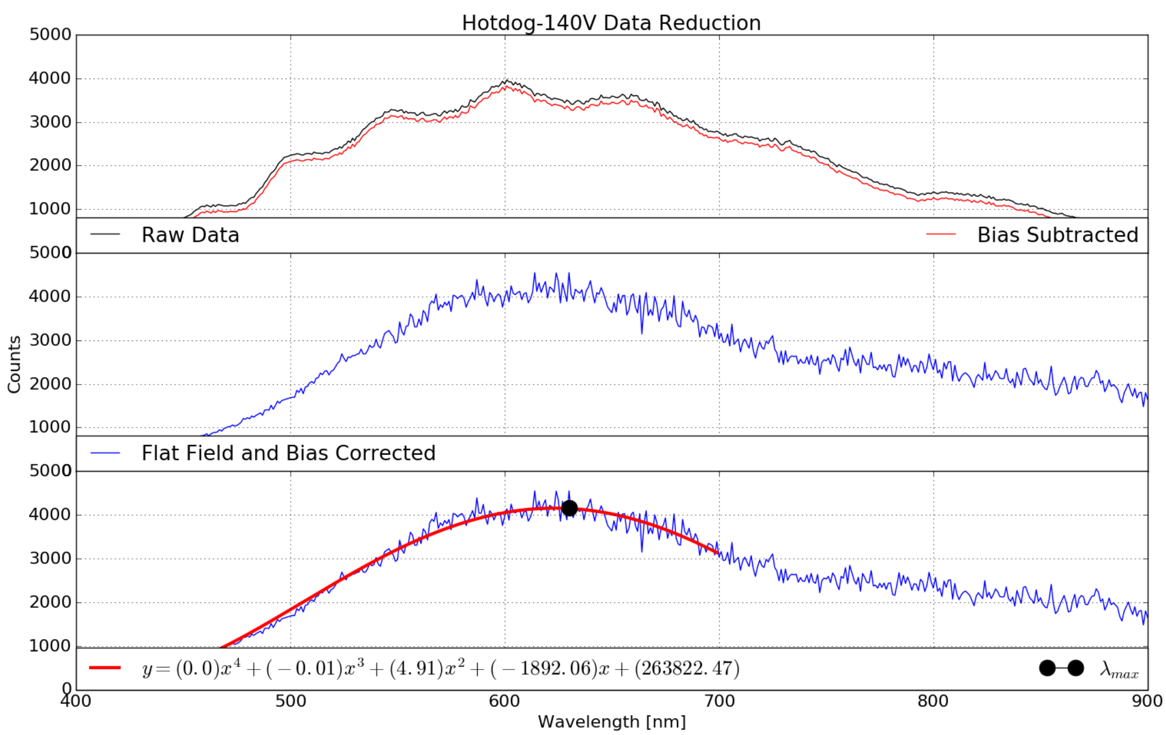

Figure 2: Data Reduction and Analyses of Hotdog-140V. $\lambda_{max} = 630$ [nm].

Discussion

Using Wien's displacement law, as discussed in the introduction, the determined temperatures of the 100V and 140V are:

$$T_{100V} = 4500\ [K]$$
$$T_{140V} = 4600\ [K]$$

where $\lambda_{max} = 644$ and 630 [nm] for 100V and 140V, respectively. It can be seen that the function is a good approximation, however it is not the most accurate. With that in mind, follow up analyses were conducted where a Gaussian model was fit—see Fig. 4 and 5—rather than the 4th degree polynomial. In comparison with Fig. 1 and 2, clearly, the Gaussian better models the data—barring any discrepancies near the tails that could be fixed using better initial guesses. Using this function, the corresponding temperatures are,

$$T_{100V} = 4479.13 \pm 2.9\,[K]$$
$$T_{140V} = 4607.31 \pm 2.7\,[K]$$

where the errors were determined using the returned co-variance matrix of the Gaussian fit, and $\lambda_{max} = 647.0 \pm 0.4$ and 629.0 ± 0.4 [nm] for 100V and 140V, respectively. Generally, a Gaussian most accurately represents spectra or any "peak-like" function. So it is no surprise that it correctly models the data.

Any follow up spectral analyses, such as a "mystery object," will require similar analyses. Specifically, the standard data processing and reduction procedure. Now it is clear that any follow up work should be conducted with a Gaussian fit to the spectra, as a opposed to a standard 4th degree polynomial.

Something of note is that the Gaussian (and polynomial) fits were done after manually removing the infrared excess. So the exact peak of the functions can change slightly, depending on how well the excess was removed. In the future, the infrared excess could also be fit (perhaps with a weighed fit) rather than just removing the data.

Appendix

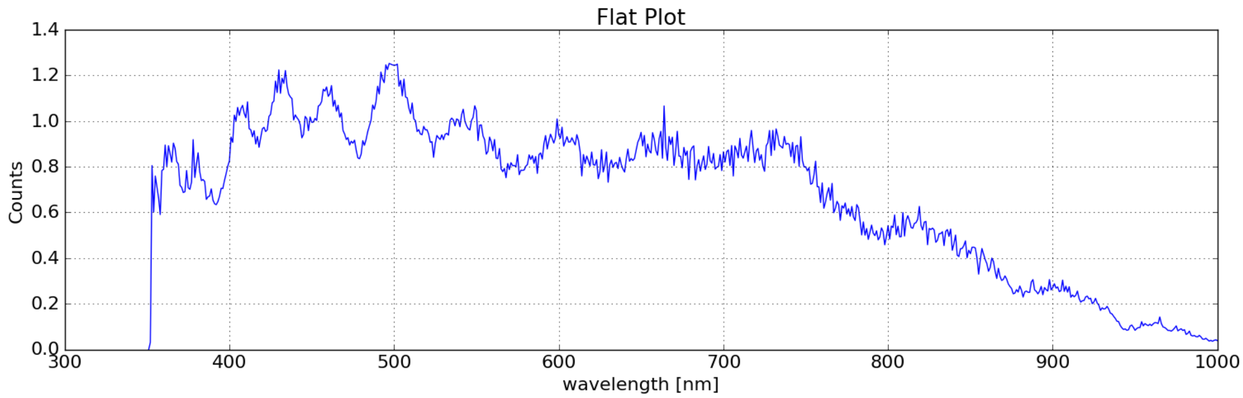

Figure 3: Flat field produced using given quartz calibration files

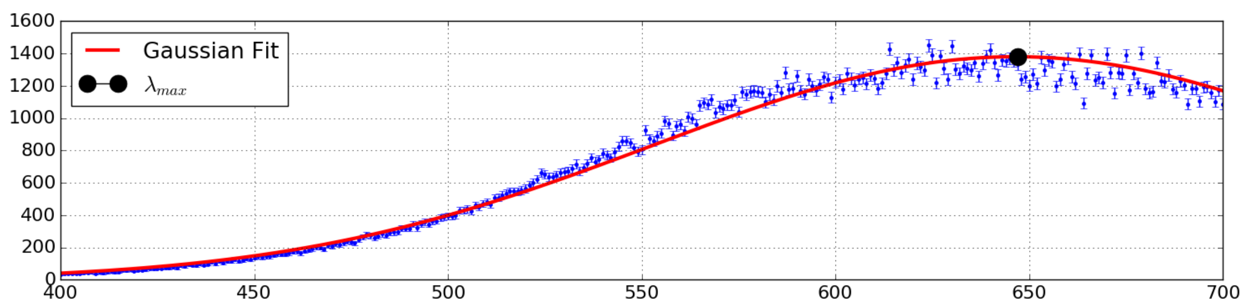

Figure 4: Gaussian fit on Hotdog-100V. $\lambda_{max} = 647.0 \pm 0.4$

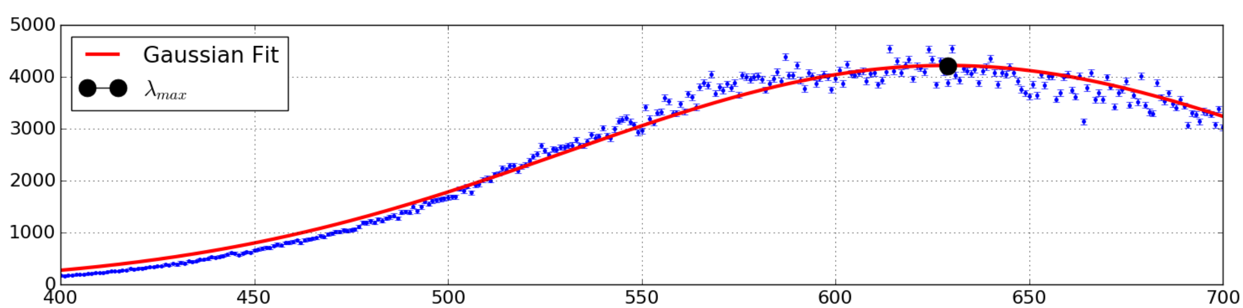

Figure 5: Gaussian fit on Hotdog-140V. $\lambda_{max} = 629.0 \pm 0.4$