Physics 266. Fall 2016. Homework 4

Due on 3 Nov 2016

SHOW ALL WORK AND HAND IN ANY CODE YOU WROTE TO DO THE CALCULATIONS.

1. Linear Fitting

A crucial, but often tedious, step in reducing optical spectroscopy is the wavelength calibration. In this procedure you measure the location (e.g., the x position on the chip) of emission lines of known wavelength, creating a list of (x, λ) pairs. This list is created either from observations of special arc lamps or from the observed positions of the night sky lines. Then some function is fit to the pairs to give λ as a function of x for any position on the chip. This function is applied to the spectrum of the science object. Note, however, that the measurement errors are all on the x points, while the λ points are assumed to be perfectly known. Thus, we will actually be fitting for x as a function of λ, i.e., $x = x(\lambda)$. On canvas under Files $\rightarrow$ Data is wavecal.txt, which contains (x, λ) pairs (x is the first column and λ is the second column). Assume that the error on each of the x points is 0.4 pixel. Use these data for the following problems.

(a) Use the linear fitting formalism (e.g., $\vec{a}$, α, $\vec{\beta}$, etc.), where the fitted parameters $\hat{\vec{a}}$ are given by:

$$\hat{\vec{a}} = \alpha^{-1} \cdot \vec{\beta}$$

to find the best-fit line (i.e, $x(\lambda) = a_0 + a_1\lambda$) to the data. Give the best-fitting parameters $\hat{a_0}$ and $\hat{a_1}$ and plot the data with the best-fit line.

(b) Use the results of part (a) to state the full covariance matrix on your fitted parameters. Also calculate χ^2 and χ^2_ν for this fit.

(c) Plot the residuals $(x(\lambda) - x_{\rm fit}(\lambda))$ as a function of λ.

(d) Now fit a quadratic function, $x(\lambda) = a_0 + a_1\lambda + a_2\lambda^2$ to the data. Give the values of $\hat{a_i}$

(e) Plot the new residuals from the quadratic fit in part (d) and calculate χ^2 and χ^2_ν. Is this a good fit?

2. Sigma clipping to determine the sky level and display limits

In the Files $\rightarrow$ Data folder on canvas is a file called `0631_gmos_q2006_i.fits`. In this problem you will implement a σ clipping algorithm and use it to choose nice limits to use when displaying the image.

(a) Find the mean and standard deviation of the data in this image.

(b) In python write a function to perform a 3σ clip on the data. This function should (i) compute μ and σ of the input data set, (ii) reject all points for which the pixel value f is more than 3σ from the mean, i.e., for which $|f - \mu| > 3\sigma$, (iii) calculate a new μ and σ for the remaining pixels. Repeat steps (ii) and (iii) until the size of the array of surviving pixels stops decreasing. Write down the final clipped values, $\mu_{\rm clip}$ and $\sigma_{\rm clip}$, for the input data. *Hint:* First, you should make a copy of the data file, since you may be modifying the data array. Next, it can be easier if you make this 2D array into a 1D array. You can do both of these via something like
`tmpdat = data.copy().flatten()`.

(c) Display the image with `imshow`, but set the vmin and vmax parameters to be $\mu_{\rm clip} - \sigma_{\rm clip}$ and $\mu_{\rm clip} + 10\sigma_{\rm clip}$, respectively. Either show the plot within an ipython notebook or save the plot as a png file and submit it.

3. Making a flat-field file A standard part of ground-based optical and near-infrared observations is the correction for pixel-to-pixel sensitivity variations in the detector. This correction is determined by (as much as possible) uniformly illuminating the detector, so that every pixel receives the same number of photons on average. This uniform illumination is either achieved by pointing the telescope at a screen inside the telescope dome that has a light shining on it ("dome flats") or by observing the night sky at twilight, where the sky is still much brighter than any stars but not so bright so that it saturates the detector ("twilight flats"). Then, variations in the output data are just due to the difference in sensitivity of the pixels and, of course, statistical noise. In this problem, you will create a flat-field file.

On canvas, under Files → Data, you will find 5 V-band flat-field exposures that were obtained with a 10-inch telescope on the roof of the Physics Building. These files are called Flat_T10_2010_V*.fits. To create the flat-field you will combine these five two-dimensional data sets by taking the mean to create a final two-dimensional data set (similar to what you did with the bias frames in an earlier homework). However, because the average photon rate can be slightly different from exposure to exposure (especially true if you are using the twilight sky to determine your flat-field corrections), **you need to divide each input file by its median data value before averaging the files together.** Submit your code for doing this, as well as a plot of your final combined flat-field image, either within an ipython notebook or as a separately submitted png file.