UCF Physics: AST 5765/4762: (Advanced) Astronomical Data Analysis

Fall 2019 Homework 6

Due Tuesday 8 October 2019

Work:
Become sufficiently familiar with fitting to:

1. Understand how the *maximum likelihood method* leads to *least squares* for Gaussian errors.
2. Be able to derive χ^2 from memory.
3. Fit linear models to data.
4. Use Python routines to fit more-complex models to data.
5. Decide whether to believe a fit.

Become sufficiently familiar with CCDs to:

1. Understand conceptually how CCDs work.
2. Understand the sources of systematic and random error in CCD data.
3. Display and explore an astronomical image with Python and `ds9`.

Resources:

1. Chapters 3 through 4.5 of Howell (**DUE** before class Thursday 10 October 2019)
2. **AST 5765 only:** Chapter 15 of Press *especially 15.6 and 15.8* (**Recommend** you read this before class Tuesday, 8 October 2019). Skim/skip sections covered by Bevington.
3. `Files/python/linfit.py` (READ THE DOCSTRING!)
4. `Files/python/gaussian.py` (READ THE DOCSTRING!)
5. **AST 5765 only:** Understand all of `linfit.py`, especially the covariance matrix and the probability.

Hand in:

1. (10 points) Create a sample of 100 draws from the uniform distribution between 0 and 10. These are x values. Calculate $f(x) = 3.2x + 1.2$. Create a sample of 100 draws from the Gaussian distribution with $\sigma = 0.5$ and $\mu = 0$. These are measurement errors in f. Add them to the f values. You now have a synthetic dataset. Plot it.
2. (10 points) Use the routine `linfit` to fit a linear model to the data in the previous problem. Assume that the points each have an uncertainty in y of 0.5 (this is important, so explain why it makes a difference). What are the fitted parameters of the model? Are they within 3σ of the parameters of the true line (the one you used to make the data)?

3. (10 points) What is the probability that you would get a higher χ^2 (i.e., a worse fit) by chance, if the data came from the fitted model and had the stated random error level? Plot the data and model, with reasonable axis labels and title. Save a PNG file.

4. (10 points) Repeat the previous problems, but fit a line to *quadratic* data:
$f(x) = 3.2x^2 + 1.2$. Does the model fit the data? Give two reasons why or why not.

5. (10 points) After bias subtraction, a flat field image has a mean value of 32 ADU and a standard deviation of 2 ADU. Since this is Poisson noise, what is the gain of the CCD amplifier?

   The following questions continue from the AST 5765 problem of HW5.

6. **AST 5765 only, extra credit for AST 4762:** (10 points) Make an array containing two 10,000-element arrays with y and x input values for the function, respectively, as follows: For x, generate a Gaussian distribution of 10,000 values with $\sigma = 1$ and $\bar{x} = 2$. For y use 10,000 Poisson values with N = 500. Calculate f. Plot the histogram of f and make a PNG file of the plot.

7. **AST 5765 only, extra credit for AST 4762:** (10 points) Estimate f and its error by fitting a Gaussian to the histogram to find the center and width. The histogram is skewed, which is the point of this exercise. You will have to restrict the fit to the region near the peak. You will also need to include a region of zero-valued bins wherever there are no data, or the fit will be wrong. Also make histograms of the y and x input arrays and fit them. See `gaussian.py` for a routine to fit a Gaussian. Plot the fit on top of the histogram in each case and save a PNG file. Also copy your fit centers and widths into your main homework file in comments or a dummy string.

8. **AST 5765 only, extra credit for AST 4762:** (10 points) Use analytical formulae to calculate f and its error using the mean x and y values estimated in the previous problem. How do your "traditional" value and error differ from your Monte Carlo values? Comment on the benefits and limitations of the Monte Carlo approach in this case. Which is more correct, analytical or Monte Carlo?

9. (10 points) Include a copy of your class log file in your handin. Print the Git log for your homework.