ASTRO 410 — Homework 2

DUE: 2/23/2023

IMPORTANT: Submission of the homework should include (1) a report in pdf format prepared with Latex (encouraged) or other programs, detailing your answers to the questions and results (e.g., plots or tables); (2) all your computer programs; (3) all output files generated by your programs; and (4) a README file that lists all the files included, and instructions to compile and run your programs. All files should be submitted as a single tarred, gzipped file named hw2-lastname.tgz or hw2-lastname.tar.gz. The file when expanded should yield a directory named hw2-lastname. Submit your homework via CANVAS. Delays in the submission of homework sets will be penalized by deducting 10% of the points per day.

You can earn extra 10 points if you write your own least-squares fitting code that implements the Levenberg-Marquardt algorithm, or you can use the sample codes provided. All students would need to use a visualization package of your choice (e.g., matplotlib, gnuplot, IDL, etc), or write your own code, to make plots for this assignment.

This problem set trains skills in least-squares fitting and data analysis, and data visualization and presentation.

1. **[30 points] Write a least-squares fitting code that implements the Levenberg-Marquardt algorithm.**

   [GRADING INSTRUCTION: The students should indicate in the README file if they write their own programs or use others. If the student writes their own Levenberg-Marquardt code which work correctly, then give full 30+10 points (extra 10 points); if they use the codes I provided give 20 points, if they use built-in or third-party functions, then give 15 points.]

2. **[45 points] Use the above least-squares fitting code to fit the data hw2_fitting.dat on CANVAS with two functions: a Lorentzian as in Equation (1), and a Gaussian as in Equation (2).**

$$\phi(\nu) = \frac{1}{\pi} \frac{\alpha_L}{(\nu - \nu_0)^2 + {\alpha_L}^2} \tag{1}$$

$$\phi(\nu) = \frac{1}{\alpha_D} \sqrt{\frac{\ln 2}{\pi}} e^{\frac{-(\ln 2)(\nu-\nu_0)^2}{{\alpha_D}^2}} \tag{2}$$

The data file has 3 columns, ν, ϕ, and e, where ν is the frequency, ϕ is the line strength, and e is the estimated error in each ϕ. Thus, we have two free parameters to fit for each function: ν_0 and α_L for the Lorentzian, whereas ν_0 and α_D for the Gaussian function.

[GRADING INSTRUCTION: (a) correct derivation of the first and second derivatives of each function (15 points); (b) correct construction of the matrices to use in the Levenberg-Marquardt code (15 points); (c) correct fitting parameters for each function, including the values of the least squares (15 points).]

3. **[25 points] Plot the data and the fitting curves, be sure to include the error-bars of the data. Which function fits the data better and why?**

   [GRADING INSTRUCTION: (a) correct plot of the data with error bars (10 points); (b) correct plot of both fitting curves (10 points); (c) correct answer with reasoning which function fits better (5 points).]