FRI Astronomy Lab #5

Goal: In the last lab you got your first glimpse of a Fourier transform. In this lab you will learn more about analyzing light curves using Fourier transforms. Using `Mathematica`, you will see the effect that noise has on the Fourier signal. You will then use the program `Period04` for a systematic investigation of the frequencies (and periods) that are present in a data set on a pulsating star.

Instructions

1. Download from the web and open the file
   `http://www.as.utexas.edu/~keatonb/lab5_2014.tar.gz`
   This file should unpack in your Downloads directory. If you can't find it, ask for help.

2. Double-click on the file `noise.nb`. This is a `Mathematica` notebook file, so `Mathematica` will automatically start.

3. Follow the instructions which are given in the notebook file; they are given as *comments* which are enclosed within matching pairs of `(*` and `*)`.

   When doing the noise calculations for noise levels of 0.1, 0.5, 1.0, and 2.0, do not erase the old plots; scroll down and simply calculate new ones. This way you can turn in a finished `Mathematica` notebook that shows all of your work.

4. Do each noise level 3 times. The noise is random and different each time so you should get 3 different estimates for the frequency. Use these 3 estimates and compute their average and standard deviation. Enter these values in the notebook in a way that I can see them. Does the standard deviation go up or down as the noise level increases? What does increasing the time base of the observations/simulations do?

5. `Save` and `Close` the notebook. If you'd like to be extra nice, also save a `PDF` version of this notebook to submit. You will be required to submit the completed notebook with the answers to the above questions on Canvas at the end of the lab.

6. Now start the program `Period04` from Spotlight or in Finder under Applications.

7. `Import` the file `1504.dat` as a "time-string". [Note: This step may be difficult due to the cumbersome way in which directories are mounted. In the pulldown menu select the name of your machine `acc##` and then click on `Network`. Continue tunneling down until you reach the location in your home directory where the downloaded file is]. With the `Time String` tab highlighted, de-select "Time string is in magnitudes," and click on `Display Graph` to see a plot of the data. You can zoom in with the mouse.

8. Now highlight the `Fourier` tab and calculate a Fourier transform of the data. Set the upper limit of the frequency range to be something sensible and then hit `Calculate` [Hint: for now the smallest periods we are interested in are about 100 seconds, so what frequency (in hz) does this correspond to?].

   The program will ask you if you would like to subtract a zero point and if you would like to "include this frequency". Answer yes to both questions. Click on `Display Graph` to see the FT. It is also scalable with the mouse.

9. Now click on the `Fit` tab. By selecting frequencies to fit you can fit a sine term to the data, allowing you to determine the amplitude and frequency of the mode. Select the checkbox by the frequency, click `Calculate` (this finds the best fit amplitude and phase for a fixed value of the frequency) and then click `Improve all` (this finds the best fit by also allowing the frequency to vary).

10. Now go to the `Time String` tab and look at the graph. You should see the data with your fit over-plotted on it (you may have to zoom in).

11. Now go back to the `Fourier` tab and calculate a Fourier transform of the data, this time with the "residuals at original" radio button selected. What this does is to subtract your current fit from the data and then just do an FT of what is left, also called "pre-whitening."

12. Use `Fit` to add this frequency to the total fit. Keep repeating this cycle of finding new frequencies until you have found at least 7 frequencies. Export these frequencies to a file called `freq1.txt`.

13. Next, import a new light curve file, `GD154_tot.dat` (this light curve combines multiple nights of observations on this same star), and repeat the above analysis, i.e., find the 7 largest amplitude periodicities in its light curve and write them out to the file `freq2.txt`. Also, write a `jpg` image of the FT of this data set (before peaks were removed) and an image of a section of the light curve with the best fit on top of it by navigating to `Graph>Export Graph`.

    Notice that the biggest peak in the FT appears to be split into several peaks. This is caused by the gaps in the data and is called "aliasing".

14. Submit both lists of frequencies and the images of the FT and the light curve fit with your Mathematica notebook (either `PDF` or `nb` file) to Canvas.

15. Bask in the glory of a job well done. . .