Kepler LLSQ

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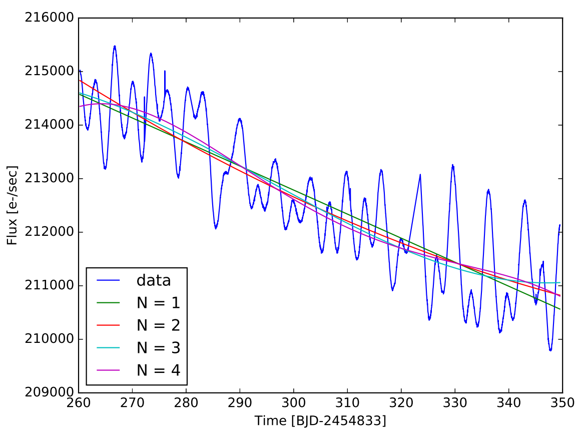
Detrending Kepler data

1. See Figure 1a

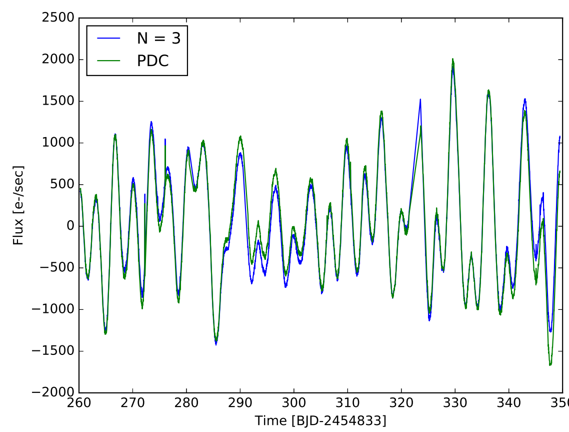
2. Trendlines with $N = 1, 2, 3, 4$ are plotted with the raw lightcurve in Figure 1a. While the $N = 4$ trendline appears to fit the data the best, care must be taken to not overfit the data and remove what may be a real signal. See below.

3. After fitting and subtracting a $N = 3$ polynomial from the raw data, the agreement with the Kepler PDC lightcurve is excellent, as can be seen in Figure 1b. The agreement would have been worse if the data had been detrended with a $N = 4$ polynomial.

4. The remaining wiggles in the lightcurve could be due to either starspots or pulsations. However, if starspots were the cause, the peaks and troughs should not have the same overall shape. Because the peaks and troughs are very sinusoidal in shape, I believe the wiggles are due mostly to pulsations.



(a) Raw lightcurve with trendlines, $N = 1, 2, 3, 4$



(b) Detrended lightcurve, $N = 3$

Figure 1: Fitting and detrending lightcurve

Analyzing Kepler data

1. Done.
2. The first coefficient returned is the total power. The following coefficients up to the halfway point increase from zero. Past the halfway point, the coefficients are negative and increase toward zero.
3. See Figure 2.
4. The two highest peaks of power correspond to frequencies of 0.15 and 0.30 per day. These correspond to periods of 6.7 and 3.3 days, respectively. Because these periods differ by almost exactly a factor of two, they most likely represent two modes of oscillation.
5. The data is not periodic, i.e. the signal does not end at its starting value. Because the FFT assumes the data is periodic, the difference of the endpoints introduces a jump discontinuity, which produces noise in the power spectrum.

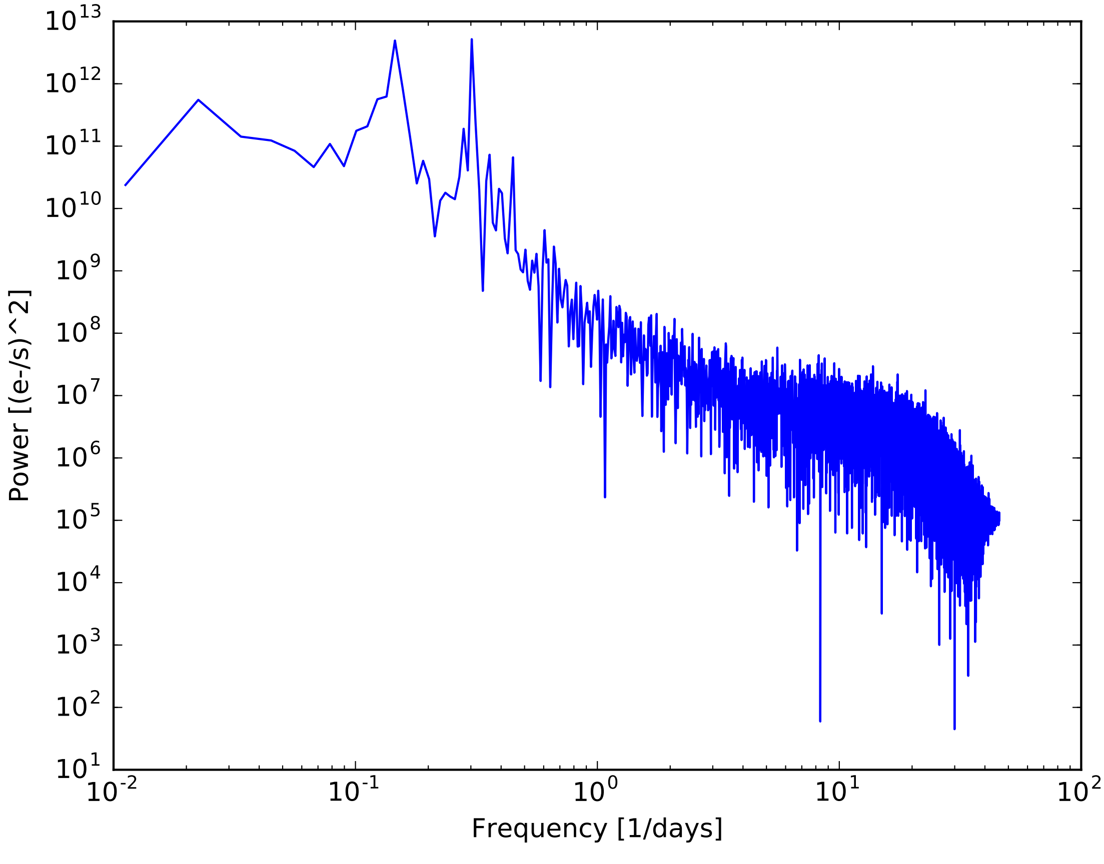


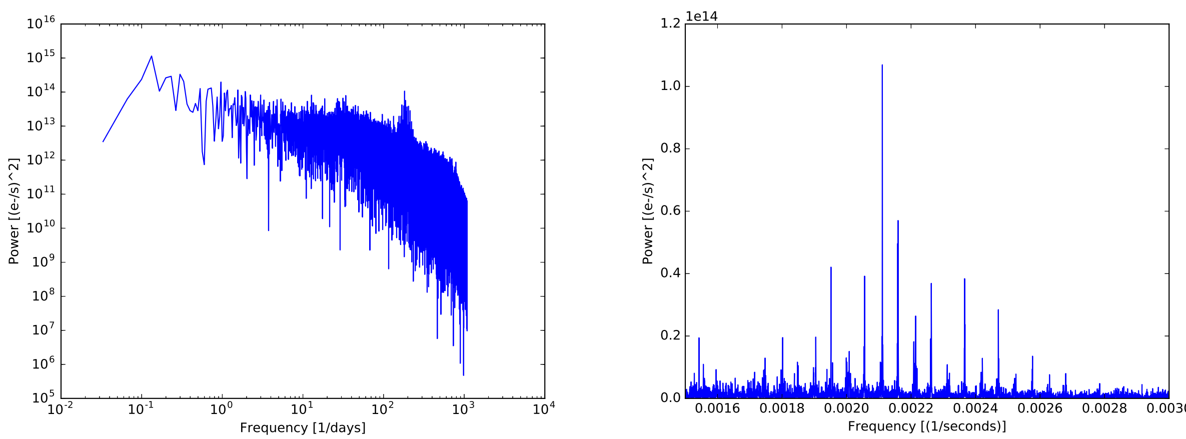
Figure 2: Power spectrum

Asteroseismology

1. The full power spectrum is plotted in Figure 3a. Due to the larger number of data points, a wider range of frequencies is sampled compared with Figure 2. There is a significant bump in the power spectrum near a frequency of 0.002.

2. The peak frequency of 16 Cyg a's oscillations is 0.0021 mHz, corresponding to a period of about 8 minutes. For the Sun, the peak occurs at 0.003 mHz, corresponding to a period of about 5.5 minutes. The peak oscillations are significantly faster on the Sun than on 16 Cyg a.

3. These oscillations are known as p-modes, which are essentially acoustic waves in the star. From their distribution of frequencies, the sound speed inside the star can be measured. A faster oscillation in the Sun indicates a higher sound speed. Since $c_s^2 = \gamma \frac{P}{\rho}$, these measurements can be used to probe the internal structure of the star.



(a) Full power spectrum, log-log axes

(b) P-modes, linear axes

Figure 3: Power spectrum of 16 Cyg a