Tracking Spectral Noise Lines in Advanced LIGO Data

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Introduction

We are developing a method that will track the frequencies of the various noise sources which obscure Advanced LIGO data. Preliminary data were taken from Advanced LIGO's ER7 run (specifically June 7, 2015), from both the Livingston (L1) and Hanford (H1) detectors.

Methods

We use Python for scripting, particularly a package called GWpy, which provides specific tools for studying data from gravitational-wave detectors. We identify the exact frequencies of the noise sources present in our time series using a high resolution power spectral density. We then heterodyne to determine if a given spectral line wanders in frequency over time. To do this, we multiply gravitational wave strain, *h(t)* by a complex exponential, $H(g,t) = e^{i2\pi gt}$, to isolate a desired frequency, and then integrate over time and divide by the length of time to get an average:

$$Z = \frac{1}{T}\int_0^T h(t)H(g,t)dt$$

When we do this for a stretch of data, *Z* becomes *Z(t)*. This allows us to pick out frequencies close to the heterodyne frequencies, suppressing all others because the heterodyne averages to zero for them. The output of the heterodyne is a complex number, which can be separated into magnitude and phase components. We examine the heterodyne magnitude and phase plots to determine how the signal frequency changes over time.

Conclusions

We have found that heterodyning is an efficient and effective method for spectral line tracking. Our future goals are to refine the method and to automate the process to constantly analyze new data minute by minute in quasi-real time. The results will help commissioners improve the detectors, and help data analysts be more immune to noise effects in astrophysical searches. This will provide beneficial insight for improving the quality of the data and the sensitivity to gravitational waves from spinning neutron stars and other astrophysical sources.

Results

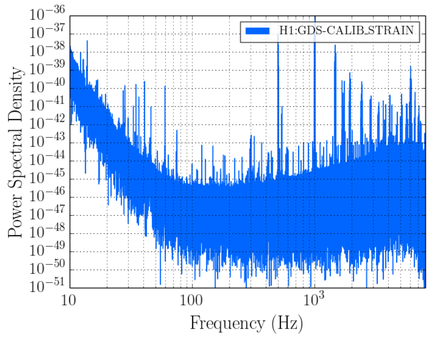

Figure 1: Power spectral density of strain data from the H1 detector on June 7, 2015 (ER7).

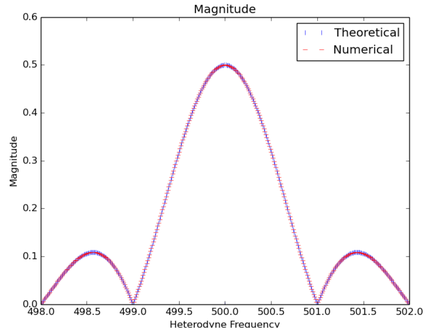

Figure 2: Theoretical and numerical calculations of heterodyne magnitude for various frequencies.

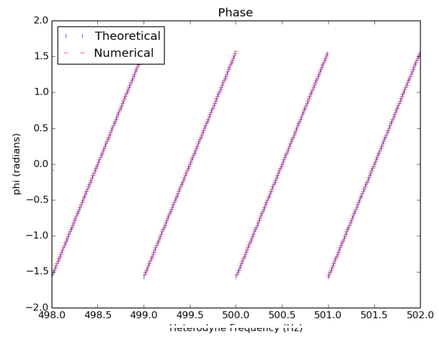

Figure 3: Theoretical and numerical calculations of heterodyne phase for various frequencies. We unwrap to put all phase points between -π/2 and π/2.

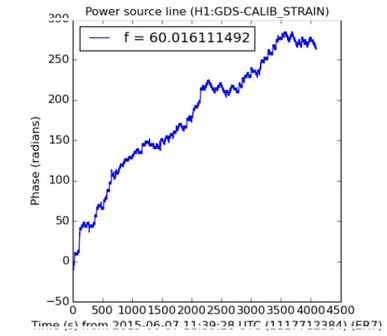

Figure 4: Heterodyne phase of the H1 power line.

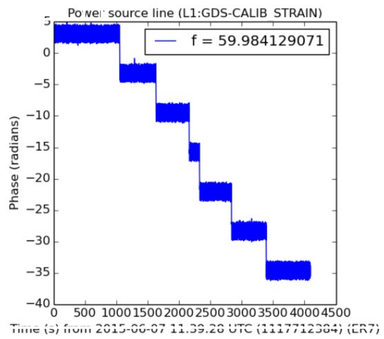

Figure 5: Heterodyne phase of the L1 power line.

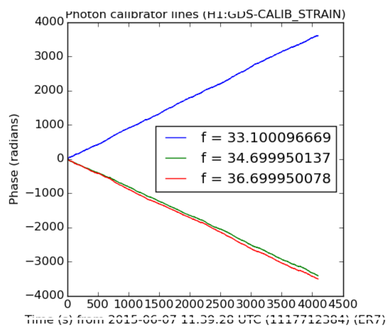

Figure 6: Heterodyne phase of the H1 low frequency photon calibrator lines.

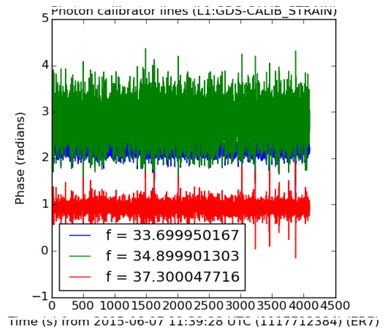

Figure 7: Heterodyne phase of the L1 low frequency photon calibrator lines.

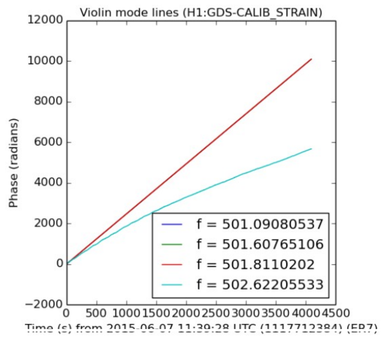

Figure 8: Heterodyne phase of the first several H1 violin modes.

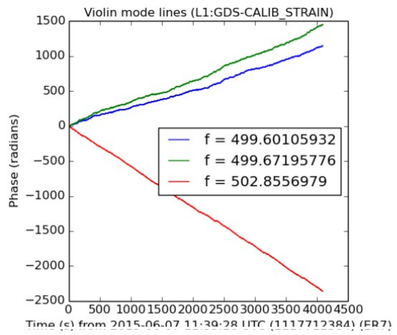

Figure 9: Heterodyne phase of the first several L1 violin modes.

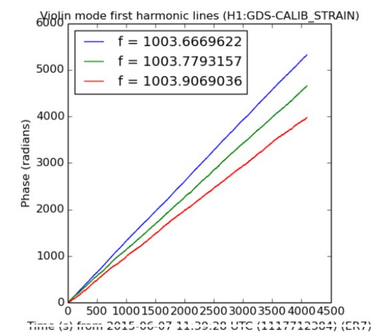

Figure 10: Heterodyne phase of the first several H1 violin mode harmonics.

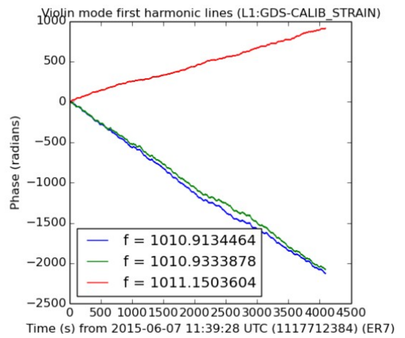

Figure 11: Heterodyne phase of the first several L1 violin mode harmonics.

References

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