Expanding the Fraction of the Universe In Which We Can Observe Supernova Made Gravitational Waves

What are Gravitational Waves?

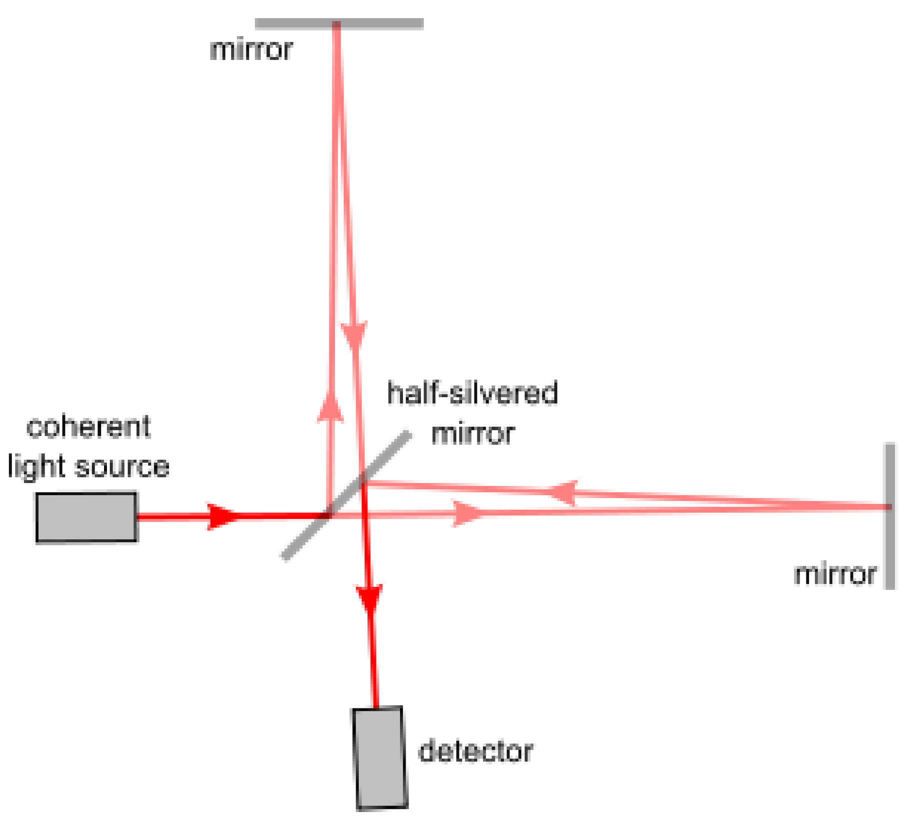
Gravitational waves are a phenomena described by Einstein's Theory of General Relativity. When a high mass system (like a supernova, or certain binary systems) accelerates, it creates waves in space-time called gravitational waves. This waves stretch and squeeze the space-time they pass through, thus having an observable effect. Gravitational waves, like light, also have polarizations, referred to the h+ and hx ("h plus" and "h cross") polarizations.

Why are Gravitational Waves Important?

Gravitational waves can propagate through space-time without interfering with anything else, unlike light which can hit dust or other obstacles and change properties (like color, or direction). This means that gravitational waves can be used to gain information about phenomena that we can't otherwise get light from (like the interior of a supernova).

So How Do we Find Gravitational Waves?

Gravitational waves are hard to detect, as they cause very small changes to space-time. We can detect them using an interferometer: an apparatus consisting of two "arms" that project a laser down the arms. The laser hits the mirrors at the end of each arm, and return to a detector. Since we know the length of the arms of the interferometer, and the speed of light, we can calculate the time it will take for each beam to return from its arm and hit the detector. Thus, a change in the beams being detected corresponds to a change in one or both of the arms of the interferometer.



Pictured left: a diagram of the type of interferometer used by scientists who are a part of the Laser Interferometer Gravitational-Wave Observatory experiment (LIGO for short). Image courtesy of Wikipedia (http://en.wikipedia.org/wiki/File:Interferometer.svg , accessed 03/27).

The Problem with Gravitational Waves

The issue with simply detecting gravitational waves, however, is that they are very small. So much so, that so far attempts to measure them have run into the issue of noise overpowering potential signals, the source of which ranges from the vibration of the mirrors (since they contain heat energy), to the passing of trucks overhead the 4 kilometer long arms.

The Solution to Noise

While some scientists work on reducing noise in the LIGO systems by physically stabilizing the systems, others work with 'cuts', or techniques to get signals out of the noise by using expected properties of the waves themselves. This is my work on the subject: proving the validity of one such method of noise reduction.

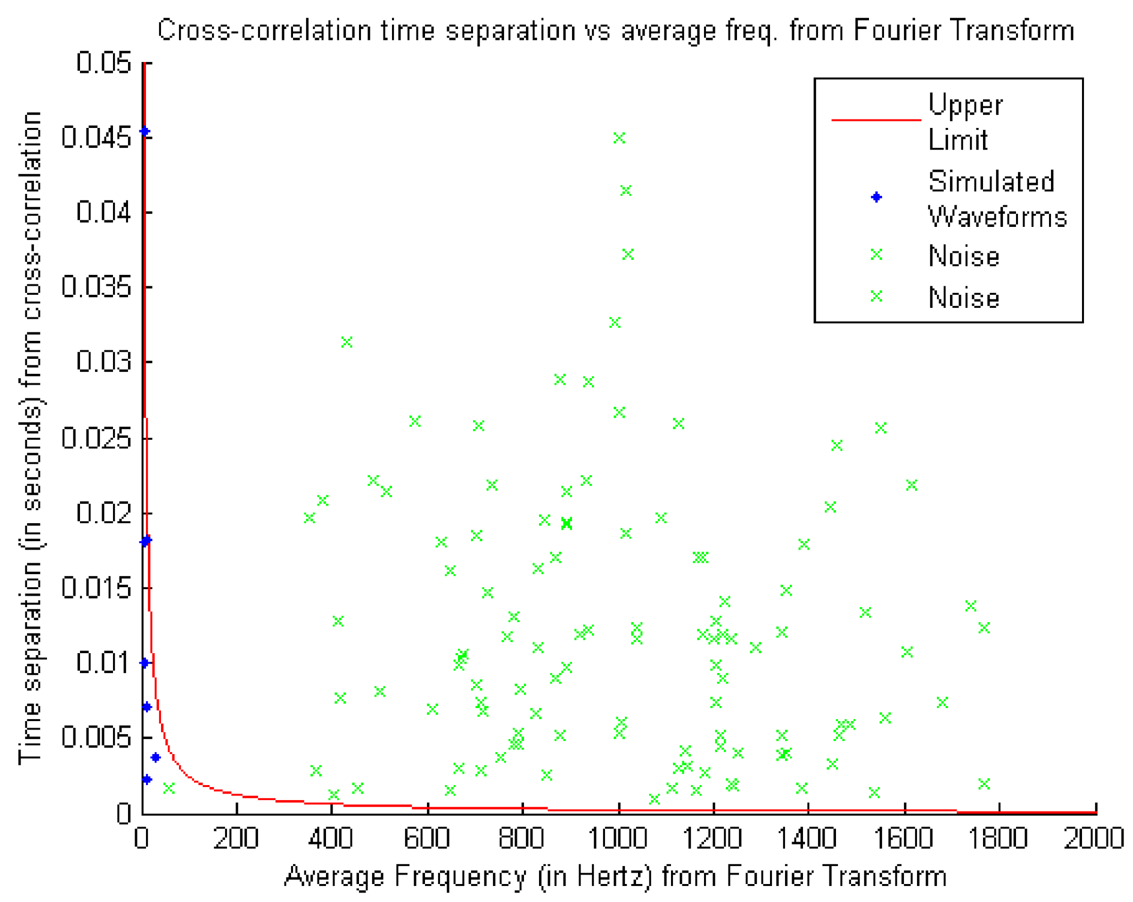
The Conjecture

The conjecture my research seeks to prove is the following: the two polarizations of gravitational waves from the same source have a maximum time separation corresponding to one quarter of the characteristic period of the average of the waves. In other words, given the average of the periods between two polarizations, there is a maximum amount of time between the detection of one polarization and the detection of the other; detections outside this maximum time limit are noise and can be discarded.

Proving the Conjecture

This conjecture has a two part proof: a theoretical one and an analytical one. On the theoretical side of things, one must show that the maximum phase difference between the two polarizations is such that the time difference is, at most, 1/4th the characteristic period. On the analytical side of things, simulated gravitational wave forms can be analyzed using a technique called 'cross correlation' to see if simulated waveforms obey this limit, and equally importantly that noise does not usually follow this limit.

Pictured right: the plot of my analytical work so far. The problem so far has been a lack of simulated waveforms with both polarizations present; most simulations only include one of the two. Of the data thus far gathered, two points lie above the expected curve. It is currently uncertain if this is an issue with the simulations, the method used to calculate the time delay, or something wrong with the theory being tested. Note that most of the simulated noise lies above the curve, this is good news for us!



The Road Ahead

There still remains a lot of work to do on improving the ability of LIGO to detect supernova-made gravitational waves. The proof of this conjecture is still a work in progress, and more simulations involving both polarizations of a gravitational wave need to be produced to get results for the analytical work. This summer is planned to be a multi-month jam to get this conjecture proven; expect to see a paper published this year on the matter!