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DETERMINATION OF SIGNAL PARAMETERS FOR GRAVITATIONAL WAVE BURSTS

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Three laser interferometric gravitational wave detectors separated by large distances enable one to uniquely identify the source direction and the waveforms corresponding to the two independent polarizations of the incoming gravitational wave. Here we summarize the results in our two previous papers[1,2] and the extensions of our method.

Three detectors separated by large distances supply three independent functions of time which are the receiver responses. They also provide two independent constants: The relative time delays between the events as measured with respect to one receiver. The functions associated with the gravitational wave are the two wave amplitudes corresponding to the two independent polarizations of the wave. In addition, two constants which identify the source direction have to be determined. From the description above, we see that this particular receiver configuration has enough information to uniquely compute the parameters of the wave.

We solve for a given detector output in terms of the other two detector outputs. The data supplied by the first detector and the computed output for it using the other two detector responses should be identical if the correct source location is substituted in the computed output. We compare the functions by integrating the square of their difference over the duration of the burst. By minimizing this difference function with respect to the parameters defining the source direction, we compute the location of the source and the two amplitudes of the incoming gravitational wave. This method works for any gravitational wave burst, independently of the time dependence of the wave's two amplitudes. We have developed methods which handle noisy waveforms with near optimal filtering. For details, see references.

We implemented the method numerically using simulated data as the receiver responses. We choose several detector configurations: (a) two detectors in the United States of America, located on the East and the West coasts and one detector in Europe located somewhere in Southern Germany. (b) two detectors in the United States of America, located on the East and the West coasts and one detector located in Australia near Perth. The orientation of the detectors in the configurations described above are chosen to optimize the mean-coincidence probability for sources in the Virgo cluster of galaxies and for randomly distributed sources. We also considered a case in which one of the detectors is rotated by 45 degrees from the optimal orientation. We used sinusoidal and arbitrary waveforms for the incoming gravitational radiation. The duration of the pulses are randomly selected to place their main Fourier amplitude within 500 to 2500 Hz bandwidth. The width of the spectrum of the pulse is about 800 Hz. For a signal-to-noise ratio of at least 5 at each detector, we find that the method without optimal filtering enables us to determine the source location within an average solid angle of 1×10^{-4} steradians while the filtered method gives an average uncertainty 2×10^{-5} steradians in the source direction. Higher signal-to-noise ratios lead to better results. The results are insensitive to the shape of the pulse as predicted by the theory.

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We plan to extend this method to networks of four or more detectors and to networks in which two of the detectors are at the same location but rotated with respect to each other. We also plan to extend this method to waves originated from coalescing binaries, to continuous gravitational signals from rotating neutron stars, to waves from the stochastic background.

References

[1] Y. Gürsel and M. Tinto, in *The Proceedings of the Fifth Marcel Grossmann Meeting*, edited by R. Ruffini and D. Blair, in press.

[2] Y. Gürsel and M. Tinto, Caltech Theoretical Astrophysics preprint.