Seismic Cloaking for LIGO

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Abstract

Metamaterials are carefully designed building blocks densely packed into a structure. They are usually artificially made, but new developments indicate metamaterials could be made out of natural materials such as trees. These new metamaterials offer a potential avenue for reducing seismic noise at low frequencies, which are typically from human sources. Seismic noise is an issue for highly precise interferometers, such as those used for gravitational wave (GW) detectors. As an example, the strain amplitude of GW170817 (the 2017 binary neutron star merger) was on the order of 10^{-22}, while average seismic activity at LIGO-Livingston and LIGO-Hanford is ~10^{-9} at 10 Hz. Skillful detector design has vastly reduced seismic noise, and we are able to measure the first GW signals. In this study, we investigate the feasibility of using trees as a seismic metamaterial that could further shield the LIGO detectors from seismic activity. This seismic cloak would reduce low frequency surface waves away from affecting the detector, thereby increasing sensitivity. This study models the energy transfer as waves pass through bandgap filters to see the extent of noise reduction. We start with acoustic cloaking as an analog for seismic cloaking to quantify the relationship between the incoming waves and the structure of the cloak. Our goal is to quantify the energy transfer near the cloak to determine how the detectors can be shielded from seismic activity. Future directions of this work would move towards solving the full scale elastodynamic equations to build a realistic model of the environment around the LIGO detectors. Results from this work could have a future impact on large-scale high sensitivity detectors.