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Seismic noise reduction for terrestrial gravitational wave detectors

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Abstract. Gravitational Wave detectors are ultimately vibration detectors. They transform the vibrations of space-time into electrical vibrations that can be measured. Seismic noise is one of these unavoidable sources of noise as the terrestrial detectors are connected to the ground, this is a constant source of noise. One way to deal with this noise is to make a suspension that isolates the experiment to the ground, at least reduces the coupling between ground and the experiment. This work shows the way to design such suspensions that does not compromise the overall performance of such detectors.

Keywords: Gravitational Wave, Vibration reduction, seismic noise, suspension, Gravitational Wave detectors

Introduction. Gravitational waves (GW) are space-time ripples generated by accelerated massive objects, to have a reasonable intensity, these massive objects must be of a cosmic origin like compact stars such as Neutron Stars or Black Holes. Considering the Einstein General Theory of Relativity, these GW move at the speed of light and can accelerate masses or excite quadrupolar normal-modes of elastic bodies as the equivalent principle predicts. The potential sources of GWs include binary compact star systems composed of white dwarfs, neutron stars and black holes.

The existence of GW is also a consequence of the Lorentz Covariance of Einstein General Theory of Relativity. GW does not exist in the Newtonian theory of gravitation, which postulates that physical interactions propagate at infinite speed.

The first detection of GWs came from the inward spiral and merger of the Black Hole (BH) binary. The event is called GW150914, and the name is given by the Letters GW followed by the year, month and day of the detection, then the detection happened on September 14, 2015. In 2017 a simultaneous detection of GW radiation and electromagnetic radiation was made from what is called a hipernova, a binary Neutron Star (NS) system that merged. It is called GW170817, which could have started the era of multi-messenger astronomy, which involves GW, optical radiation, radio, gamma-rays and X-rays radiation. Studying the universe with these different types of radiation opens a new era for understanding the universe.

In 2017, the Nobel Prize in Physics was awarded to Barry Barish, Kip Thorne and Rainer Weiss for their role in detecting gravitational waves. Before the first GW detection, there was indirect evidence of these GW. Measurements of the Hulse and Taylor binary pulsar system suggested that GW was more than a hypothetical concept, at least for the emission of such waves; the authors of this measurement won the Nobel prize. This system is one of the potential sources of detectable gravitational waves, but because of the frequency with which this system operates, a new kind of detector can detect much smaller frequencies than the one that detected GW150914. The kind of detector responsible for this detection are interferometric ones, whose sensitivity is limited at frequencies close to 10 Hz and lower because of seismic noise on the mirrors.

These detector are vibration detectors and as such must deal with seismic noise that comes from the ground vibrations, this work deal in the ways of reducing this noise.

Methods and materials; results. The analysis is done by simulating the detector in solids models and then analyzing their performance using Finite Elements Modeling (SolidWorks software is used). The test bed is the Schenberg detector, the results can be extrapolated for other terrestrial detectors [1-3].

Conclusion. The results show that the seismic noise can be reduced to a level that allows the detection of Gravitational Waves.

References

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