Sensor networks to measure environmental noise at gravitational wave detector sites

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Current second generation of gravitational wave detectors have achieved a peak sensitivity in the order of 10^{-23} strain/$\sqrt{\mathrm{Hz}}$ for frequencies greater than 10 Hz. However the sensitivities of these detectors have been predicted to be compromised below 10 Hz due to seismic and its gravitational counterpart Newtonian noise. Hence, for current second generation and future third generation underground gravitational wave detectors like Einstein Telescope, it is important to decipher the spatio-temporal properties of such environmental noise sources near the detector site. While environmental noise can be magnetic, electrical, seismic or acoustic in origin, special emphasis in this thesis have been given to the understanding of seismic noise propagation at the gravitational wave detector sites.

Cabled seismic sensor networks pose several restrictions on the seismic array geometry and hence are difficult to be spread out over hundreds of square kilometers of the survey region. In the context of geophysical active surveys such networks do not pose much restriction as they are mostly laid out on the field along straight lines. However, for passive seismic survey which is used for sampling the ambient noise of the Earth, cabled seismic networks are not feasible. In the case of a sparsely distributed seismic array, standalone seismometers could be used but usually the process is clumsy and requires a lot of electronics to be arranged at the site. For this purpose standalone easy to use seismometers weighing not more than a few hundred grams were designed. Such a network of seismometers can be easily deployed over thousands of square kilometers and without any compromise to data quality due to the instrument noise of the seismometer. Seismometers enabled with a 4.5 Hz geophone could achieve a sensitivity in the order of 1 ng/$\sqrt{\mathrm{Hz}}$ at 1 Hz. While the application of these seismometers is obvious in the geophysical community, they also have useful applications in the gravitational wave community. Gravity gradient noise is one of the important sources of noise at low frequencies for the current second-generation of gravitational detectors and more so for the third generation detectors like Einstein Telescope. Since gravity gradient noise is due to the seismic motion of the subsurface elements near the suspended elements of the detector, understanding the propagation characteristics of the seismic noise is important near the detector's suspended components. The use of seismometer arrays for understanding the spatio-temporal properties of seismic noise at a site typically falls under the category of passive seismic. Hence, a network of these autonomous high sensitivity seismometers can be deployed optimally at the gravitational wave detector sites to understand the content of seismic waves (body and surface wave), the surface wave dispersion and also the modal content of the surface wavefield. Further applications include the estimation of a subsurface model at the site which can be further used to estimate the gravity gradient noise associated with the observed seismic wavefield.

Other novel applications of such seismometers include earthquake early warning systems and also personnel detection schemes.