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Atmospheric noise contribution to Newtonian Noise for gravitational wave detectors

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Since the first detection of gravitational waves (GW) in 2015 by the LIGO and VI
RGO collaborations, the scientific community has been pushing for improving GW detectors as well as the analysis methods and models for noise control. The new generation of GW detectors, LISA and Einstein Telescope (ET), is expected to be orders of magnitude more sensitive than the previous ones, especially in the low-frequency band. The improved sensibility increasingly exposes the detectors to environmental noise, which must therefore be modeled in a very accurate way. One
of the most problematic noises is the one produced by local fluctuations of the gravitational acceleration—the so-called Newtonian noise (NN)—which cannot be shielded. It is thus of paramount importance to accurately estimate the different kinds of NN and, if possible, to actively subtract their effects from the measured signal.

In this talk, we discuss the contribution to NN by temperature fluctuations generated by atmospheric turbulence. These temperature fluctuations result in density fluctuations, whose spectral properties are determined by the advection by the mean wind and by the deformation by the turbulence.

We will first focus on a homogeneous and isotropic model of turbulence (HIT) in the presence of a uniform constant speed wind. Differently from previous estimates, which, within a so-called frozen-turbulence approximation, only considered the effect of wind advection, we will also take into account the continuous deformation and time-decay of turbulent structures. Our approach reproduces known results in the frozen turbulence limit. However, new and potentially important contributions from the time-decay of turbulent structures do emerge. We will consider next a wall-turbulence (WT) model of atmospheric boundary layer, in which the homogeneous isotropic turbulence hypothesis is relaxed and the variations with height of the turbulence intensity and of the wind speed are taken into account. We have evaluated the noise spectra and their dependence on the depth of the detector and the wind and the turbulence characteristics, for both HIT and WT, in the case of Gaussian time correlations.

We have derived our results with special focus on the ET geometry, but they remain valid for any ground-based GW detector. We find that at small depth and/or for high wind-speed, the NN contribution is above the ET sensitivity curve in the
low-frequency band of the spectrum.

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