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The challenge of low frequency sensitivity in ground-based GW detectors

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Within the context of Gravitational Waves (GW) detection, interferometric GW detectors have revolutionized astrophysics over the past decade, allowing the detection of relevant cosmic events which were previously unobservable. These instruments are based on the principle of the Michelson interferometer, using resonant Fabry-Perot cavities in which the main optical components (test masses, i.e. TM) are suspended as free-falling bodies in order to isolate them from the seismic disturbances.

In order to be able to detect the weak signal of a gravitational wave, it is necessary that such optical components are positioned in the so-called working-point, in which the mirrors are kept steady with respect to each other with enough accuracy in terms of residual motion, e.g. deviation from the operating point along the optical axis. Such requirements are typically of the order of $1\cdot10^{-12}$ m for the longitudinal degrees of freedom, and $1\cdot10^{-9}$ rad for the angular ones. Since the free motion of the suspended elements is orders of magnitudes larger, specific feedback control systems are necessary to sense and keep the elements in the correct operating point. As a consequence of the implementation of such feedback systems, control noise becomes one of the main offenders spoiling the detector sensitivity at low-frequency, below 40 Hz.

By addressing control noise, we aim to significantly improve the sensitivity of gravitational wave detectors at low frequencies, thereby enhancing our capability to detect and analyze gravitational waves from a wider range of astrophysical sources, especially in view of third-generation detectors which aim to further improve these noise limits. This work will provide an overview of the current status of low frequency noise for the second-generation detectors, noise reduction techniques, and future perspectives in overcoming control noise challenges to improve gravitational wave astronomy.

Primary author: MANTOVANI, Maddalena (EGO)

Co-authors: DE ROSSI, Camilla (EGO (ITALY)); Dr BERSANETTI, Diego (Istituto Nazionale di Fisica Nucleare); CASANUEVA DIAZ, Julia (EGO); PINTO, Manuel (EGO (ITALY)); VAN DAEL, Mathyn (Nikhef); BOLDRINI, Mattia (Istituto Nazionale di Fisica Nucleare); RUGGI, Paolo (EGO (ITALY)); SPINICELLI, Piernicola (EGO)

Presenter: MANTOVANI, Maddalena (EGO)

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