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Magnetic noise in Advanced Virgo

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Summary. — I present a study of the electromagnetic coupling through the coil-magnet pairs used as actuators in Advanced Virgo (AdV) Input Mirror Payloads. We first employed and validated a finite-element analysis approach, followed by a series of stimulated magnetic noise injections in the interferometer, both leading to an estimation of the magnetic noise contribution to the total AdV strain noise. At this stage, AdV seems to be unaffected by magnetic noise. However, we foresee a non-negligible coupling once AdV reaches the design sensitivity. Finally I present the most recent efforts concerning Schumann global magnetic resonances, whose detection and successful subtraction could make the observation of a Stochastic Gravitational Wave Background possible.

1. – Introduction

Advanced Virgo [1,2] is a laser interferometer devoted to the detection of gravitational waves of astrophysical and cosmological origin. The detection power lies entirely on the instrument spectral sensitivity. One of the limiting noises could be due to the magnetic coupling through the coil-magnet pairs used as actuators in payloads, to actively control the mirror test masses fine positioning.

2. – Major results

The Advanced Virgo (AdV) frequency sensitivity ($f < 50\,\text{Hz}$) is influenced by both local and global electromagnetic effects. Firstly we carried out finite-element simulations of the payload response to local environmental magnetic fields, followed by an experimental validation in a controlled environment [3]. Then a second phase of experimental measures aimed at finding the transfer function between an intentional injected magnetic field and the interferometer [4]. The results brought to two parallel estimations of the magnetic strain noise (fig. 1). The overall magnetic noise level is reassuring, but we already tested a few magnetic shielding configurations with regard to a possible future mitigation requirement.

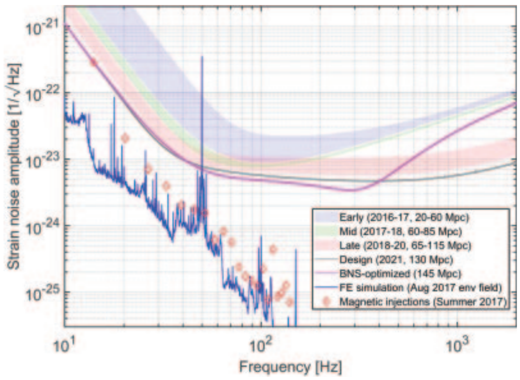

Fig. 1. – Contribution of the magnetic noise (injection: red diamonds; simulation: blue line) to the AdV sensitivity, in the frequency range of interest for astrophysical binary mergers detection. The magnetic noise estimations are compared with the most recent Virgo sensitivity limits (coloured bands).

The magnetic coupling also accounts for the correlated magnetic noise from Schumann global resonances, which threatens to contaminate the observation of a Stochastic Gravitational Wave Background in interferometric detectors [5]. We measured Schumann resonances with good resolution both at Virgo site and in the surrounding countryside. For now we reached a good level of subtraction (fig. 2), in spite of the high degree of correlation across the entire magnetic probe network, thanks to Wiener filtering [6].

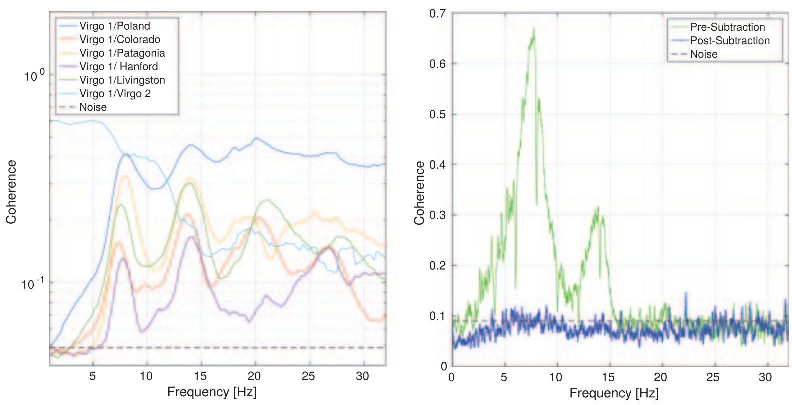

Fig. 2. – On the left: coherence between Virgo North-South magnetometer (Virgo 1) and the Poland, Colorado, Patagonia, LIGO Livingston, LIGO Hanford and Virgo East-West (Virgo 2) ones, over a week of coincident data, compared with Gaussian noise (dashed line). On the right: coherence between KAGRA and Villa Cristina magnetometers before and after Wiener filter subtraction. There is no detectable remaining peaks from the Schumann resonances. Reprinted from Coughlin M. W. *et al.*, *Phys. Rev. D*, **98** (2018) 102007, with the permission of APS Publishing.

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