PhD thesis proposal: Commissioning and characterization of variable finesse filter cavities for squeezing application in GW detectors.

Start of the PhD: 1st October 2025

Place: IJCLab, Astroparticles, Astrophysics and Cosmology pôle, Gravitational Waves group

Context:

Since the first detection of gravitational waves (GW) in 2015, hundreds of compact binary coalescences have been observed. Even better, the observation of two merging neutron stars in 2017 and the associated electromagnetic observation heralded a new area of GW astronomy.

The next generation of GW detectors Einstein Telescope (ET), will aim at reaching most of the observable Universe for compact bynary coalescences. To reach this goal, ET will have to be ten times more sensitive than the design of current generation GW detectors and even better for frequencies below a few tens of Hz. The low-frequency part is crucial, as this is where most of the signal-to-noise ratio is picked up for many targeted GW sources, especially as we probe deeper in the Universe due to increased redshift of the signals. Moreover, extending the sensitivity towards the low frequencies enables early warning and localisation of merging neutron stars. ET will start observing by the end of 2030's with upgrade phases during decades.

Objectives:

Quantum noise will be a major limiting noise of ET. Consequently, controlling and reducing it using frequency dependent squeezed states of light will be a major challenge for ET. Such states of light need the use of kilometric suspended optical cavities, called filter cavities. Moreover, the parameters of these cavities must be tunable to follow the change in the GW detector implementation. The objective of the PhD will be to develop, characterise and control a variable finesse cavity to cope with the needed in-situ tuning and/or reduce the needed length of the cavities using a linear three-mirror cavity instead of a two-mirror cavity.

The results of the PhD thesis will have an impact on the design of the squeezing filter cavities for ET.

Working environment:

The PhD candidate work will be based at IJCLab in Orsay with both simulation and experimental aspects. IJCLab hosts the CALVA platform which is designed to study the control of a suspended cavity for Advanced Virgo with a 50m-long Fabry-Perot cavity and that is under modification to host a linear suspende three-mirror cavity. Moreover, the CALVA platform is now hosting the development of an in-vacuum squeezing source. By design, the tools used on the CALVA platform are the same as for Virgo, and may by a basis for ET, which facilitates sharing technology between the systems, and allow the PhD student to be trained on a GW detector-like environment.

Provisional timetable:

The first year of the PhD will be devoted to the experimental implementation of the linear three-mirror suspended cavity on the CALVA facility, along with simulation of the impact of such cavities on the quantum noise reduction with respect to two-mirror cavities, considering loss sources both on the CALVA set-up (to be compared at the end of the PhD with experimental measurements) and for ET.

The second year will then be dedicated to the control of the linear three-mirror cavity on the CALVA facility and its characterization using to set of cavity mirrors giving to chareacteristics frequency dependency for the squeezed states of light.

Finally, during the third year, squeezed states of light will be injected into the linear three-mirror cavity to measure frequency dependent squeezing for the first time using linear suspended three-mirror cavities.

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