

# Proposal for JAE intro ICU SCHOLARSHIPS @ ICE

M. Nofrarias, June 27<sup>th</sup> 2021

## **Opto-mechanical resonators for temperature sensing in space-based gravitational wave detectors**

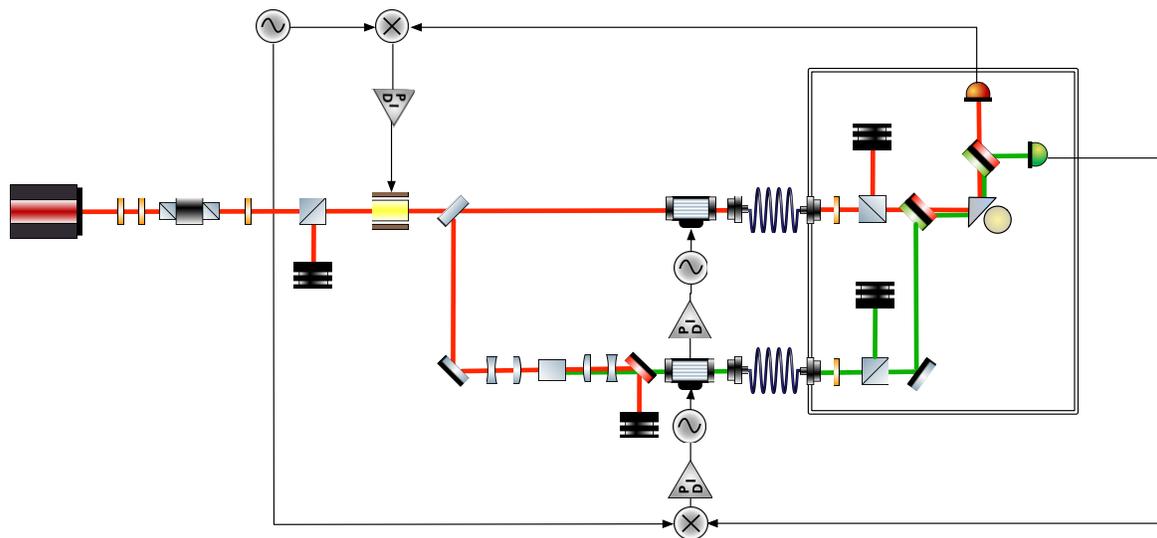
Gravitational waves are a prediction of Einstein's General Relativity recently detected by the on-ground laser interferometers LIGO. LISA (Laser Interferometer Space Antenna) is an ESA mission with expected launch in 2034 aiming to detect gravitational radiation by putting three satellites in heliocentric orbit separated 2.5 million km one from each other, forming a triangle. The Gravitational Astronomy group at ICE led the Spanish contribution --the Data and Diagnostics Subsystems-- to the precursor mission LISA Pathfinder, launched in December 2015 that successfully proved the key technologies to reach the purest free-fall in space to the date [1,2].

Temperature dependent effects are typically dominant in the low frequency regime, which is the main scientific band for space-borne gravitational detectors [3]. In LISA, temperature fluctuations in the sub-millihertz will be ubiquitous to the satellite with a potential to impact key subsystems in the measurement chain, from thermal induced forces applied directly to the test mass to temperature induced path-length variations in interferometers. In this context, the Gravitational Astronomy group at ICE is leading LETS (LISA Enhanced Temperature Subsystem), an ESA funded project which aims to design and test a prototype temperature subsystem reaching  $1\mu\text{K}/\sqrt{\text{Hz}}$  down to 1mHz, which represents a one order of magnitude improvement with respect the temperature subsystem flown in LISA Pathfinder.

Our group is exploring as well novel technologies with a strong potential impact in future space-borne gravitational wave detectors and other mission with high precision measurement requirements. This is the case of opto-mechanical resonators, as the so called Whispering Gallery Modes Resonators (WGMR). These are extremely sensitive devices (quality factors  $\sim 10^{11}$ ) which can be used as temperature sensors with sensitivities that are orders of magnitude beyond current commercial devices [4,5]. The selected candidate will work in the development of a test bench (see Figure 1) that aims to reach nano-Kelvin resolution in temperature sensing. The candidate will work in collaboration with the LETS team at ICE with the objective to extend the WGMRs results available in the literature to the sub-millihertz frequency regime, i.e. the measuring bandwidth for future gravitational wave detectors in space.

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**Figure 1 Proposed setup for the opto-mechanical temperature sensor test bench**

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- [2] M. Armano et al. Beyond the Required LISA Free-Fall Performance: New LISA Pathfinder Results down to 20uHz. *Phys. Rev. Lett.* 120, 061101 (2018)
- [3] M. Armano et al. Temperature stability in the sub-milliHertz band with LISA Pathfinder. *MNRAS* 486, 3368–3379 (2019)
- [4] W. Weng Nano-Kelvin Thermometry and Temperature Control: Beyond the Thermal Noise Limit, *Phys. Rev. Lett.* 112, 160801 (2014)
- [5] J. Lim Chasing the thermodynamical noise limit in whispering-gallery-mode resonators for ultrastable laser frequency stabilisation, *Nat. Commun.* 8, 8 (2017)