Proposal of topic of thesis

English version

Title of the topic	Experimental validation of the high precision interferometric instruments onboard LISA
Host laboratory / Doctoral school	AstroParticule et Cosmologie (APC) / ED 560 STEP'UP (Sciences de la Terre et de l'Environnement et Physique de l'Univers, Paris)
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Financial partners	CNES + CNRS/IN2P3
Profile of applicant	Knowledge in general instrumentation, system engineering, laser interferometry, numerical simulations, data analysis and astrophysics / astroparticles (engineering schools & Universities)
Short description of the topic : context of the spatial experience, applied methodology, expected results.	The LISA project of gravitational waves detection has been selected in spring 2017 as a 'Large'-class mission of the European Space Agency. This mission relies on the capability to measure, using laser interferometry, the distance fluctuations between satellites 2.5 Mkm apart, with a picometer accuracy on seconds to hours timescales. LISA is the product of an international development effort, France being part of the European collaboration providing the instrument. After a successful Phase A (feasibility studies), the project has entered its preliminary definition design study phase (Phase B) early 2022. In this context, the CNES and about fifteen French laboratories have proposed to contribute to the validation of the scientific performance of the instrument prior to flight and develop the required high-precision optical metrology benches. Two main steps of experimental validation are currently foreseen : the first with a 'reduced' instrument model (named IDS : Interferometric Detection System) starting in 2025 and the second with fully integrated models (named MOSA : Movable Optical Sub-Asembly) from 2029 on. The hereafter proposed subject is focused on the global validation process of the instrument metrological performance. Several different optical test benches are foreseen and preliminary concepts exist in order to measure characteristics such as the pathlength stability of the different interferometers onboard LISA, potential spurious couplings between the pointing direction and the optical pathlength, the quality of the emitted and received wavefront, etc. However, a direct measurement of the LISA performance is impossible on ground due to obvious limitations in propagation distance as well as environmental perturbations. Consequently, the instrument validation will rely on a ingenious combination of the different measurements performed on the different subsystems of LISA, as well as the results obtained with specifically designed lab experiments. The first goal of this thesis is therefore to review, define and evaluate, through simulations and experiments, the different optical measurements that shall be performed to determine the intrinsic performances and associated errors that can be reached. Then, the task will focus on the most suitable combinations of these measurements to fully characterise the LISA instrument prior to flight. This work will involve a deep understanding of the instrument requirements and design. For this purpose, the PhD student will work on numerical and analytical computations and on the experimental results collected by ground test benches. He/she will also study the most relevant combinations allowing to infer the scientific performance of LISA in orbit and assess their suitability to check the mission requirements. A consolidated performance tests strategy is thus expected, including the description of the required measurements and the tools necessary to process and combine their results. In relation to this long term objective, the student will also contribute to the design, performance modelling and operations of the so-called 'Beams Simulator',

	which is an optical bench to be developed at the APC to support the validation of the IDS. The design of this bench shall rely on the experimental results of current bench prototypes and the development of optical demonstrators as needed. Once completed, the 'Beams Simulator' bench shall be tested and commissioned, before being used on the IDS Engineering Model in 2025. On this topic, the objective of the thesis is to produce a detailed metrological performance model of the IDS GSEs, that could be checked against the measurement performed during the commissioning phase. This works shall be included in the general validation strategy of the LISA instrument model. For all these experimental activities and their interpretation in terms of instrumental performance, the student shall rely on the scientific and technical teams of the LISA group at the APC laboratory (including engineering support in optics, mechanics, electronics, system engineering, data analysis, quality assurance, etc). This work will also be carried out in close collaboration with the other French laboratories, the CNES and the international institutes involved in the development of the LISA instrument.