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Session 2 / **1**

Campagne de tests du démonstrateur technologique ZIFO

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La contribution française (hardware) au sein du consortium LISA se trouve principalement dans le développement de bancs de test destinés à caractériser les bancs optiques au cœur de l'instrument LISA.

Pour ce faire, un ensemble de démonstrateurs ont été développés afin d'acquérir une expertise dans le domaine de l'interférométrie hétérodyne à basse fréquence, dont le banc optique de métrologie ultrastable ZIFO (Zerodur Interferometer).

Son objectif est d'effectuer une mesure de chemin optique avec une stabilité de mesure de 10 pm/√Hz ainsi que d'identifier et de quantifier les principales sources de bruits de mesures.

Session 1 / **2**

Spectral separation of the cosmological SGWB for LISA in context of galactic and astrophysical background

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In pursuit of observing a stochastic gravitational wave background (SGWB) with LISA, it is crucial to investigate the spectral separability of cosmological, astrophysical backgrounds, and galactic foreground in order to make accurate estimations.

Our objective is to determine the observability of a cosmological background, considering the predicted astrophysical background and galactic binaries populations.

We aim to establish detectability limits for future measuring the SGWB in various cosmological models (Cosmic strings, First order phase transition).

We employ Adaptive Markov Chain Monte Carlo (Adaptive-McMC) techniques to generate estimates and characterize the posterior distribution of model parameters. Additionally, we assess the uncertainty in SGWB parameters using the inverse Fisher Information and the Whittle Likelihood method. The parameter estimation is conducted across three channels: A, E, and T. Furthermore, we simultaneously evaluate the noise levels, considering a LISA noise model and addressing multiple sources of noise contamination, as depicted in the Figure of Merit philosophy.

Session 2 / **4**

FOGOB: an optical setup for TTL estimation in LISA

Auteurs: Frederic Cleva[1]; marco nardello[2]

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The now dismissed FF-OGSE was aimed at measuring the Tilt-To-Length coupling on LISA's benches. Its "active" core is the so-called FOGOB optical bench. It delivers a reference beam (REF) and an angular jittering beam (Rx), which are used to probe the longitudinal optical path length variations induced by the Rx tilt at the MOSA level. Such coupling is connected to the internal misalignments of the MOSA.
At ARTEMIS we developed a demonstrator (FOGOB_Demo) aimed at providing a FOGOB scheme proposal through the demonstration of the critical functions the FOGOB.

The functions to be demonstrated were the following:
- Provide a flat-top intensity profile and flat wavefront to mimic the Rx beam
- Provide an angular jittering Rx beam on the associated pivot point, centered at the FOGOB_Demo's pupil within +/-15 um, with a stability better than 1 um over few hours.
- Center the REF beam on the pivot point with a precision of 2 um.
- Get a phase-lock between the two beams.
- Demonstrate a residual TTL coupling coefficient at the output pupil of less than 10 um/rad.

To reach such goals we adopted several original procedures and techniques based on the use of servo loops and lithography masks for position control, a dedicated optical setup for the realization of the flat-top, the design of optical supports with the required stability, the realization of dedicated electronics for servo-loops and signal reading.
Optical simulations made with different optical software (FRED, IfoCAD) corroborated and guided the measurements.

The setup shows a residual TTL within the specification of < 5 um/rad, with a stability better than 1 um/rad over 130 hours.
We generate a flat-top with wavefront (lambda/80) and intensity profile compliant with a negligible TTL coupling coefficient.
In addition to these remarkable performances, the demonstrator makes use of standard components, metallic breadboard (instead of zerodur based one). It allows for remote beams position control within a precision better than 0.1 microns and in a straightforward way. It is operated in a normal environment laboratory.

The prototype demonstrated the feasibility of the FOGOB and provided useful insight and techniques for future similar applications.

Session 3 / **5**

An L0L2 demonstrator pipeline for LISA

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I will describe the L0-to-L2 demonstration pipeline developed in order to address the FMT task 4.5 activity of LISA. The main goal of this activity is to show that it is possible to build a complete data analysis pipeline capable of generating L1 and L2 products from L0.5 data. The L0.5 to L1 step mainly includes on-ground processing that performs noise reduction, calculates pseudo-range

estimates, TDI and clock synchronization. The L1 to L2 step consists of source parameter estimation using Bayesian parameter estimation with nested sampling. In this work we restrict the analysis to a single galactic binary.

Session 3 / **6**

Extreme mass-ratio inspirals to probe modified gravitational-wave propagation and LCDM

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Extreme mass-ratio inspirals (EMRIs) are one of the most important sources of gravitational waves (GWs) that will be detected by LISA. Similar to compact binary mergers detected by current GW detectors, EMRIs can be used as cosmic rulers to probe the expansion of the Universe and our current cosmological paradigm, the ΛCDM model. Modified gravity theories can affect the propagation of GWs over cosmological distances, with modifications that can be parametrised in terms of phenomenological parameters that can be constrained with GW observations. In this talk, I will discuss what Bayesian constraints can be placed on a common phenomenological parametrisation for General Relativity deviations using the loudest EMRIs detected by LISA as dark standard sirens in combination with a simulated galaxy catalogue.

Session 3 / **7**

Le SL-OGSE, instrument dédié à la mesure de la lumière parasite au niveau système

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La mesure de la lumière parasite est un enjeu de premier plan dans l'intégration de tout interféromètre. C'est le cas des interféromètres dédiés à la géodésie spatiale, et bien sûr des interféromètres de la mission LISA. Le "SL-OGSE" a été conçu pour mesurer la lumière parasite cohérente au niveau système, en fin d'intégration du MOSA. Cette présentation décrira ses fonctions et donnera un aperçu de la méthode utilisée pour mesurer les amplitudes de lumière parasite cohérente, d'une façon qui permet d'identifier la source de la lumière parasite.

Session 2 / **8**

Time-delay interferometry as a coronagraph

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The Laser Interferometer Space Antenna (LISA) will be a space-borne gravitational wave (GW) detector to be launched in the next decade. LISA is designed to be sensitive to GWs in the mHz band and is expected to observe an unprecedented number of sources: quasi-monochromatic sources as galactic binaries (GBs), transient sources such as massive black hole binaries (MBHBs), extreme mass ratio inspirals, stochastic GW background and potentially unmodeled sources. The richness of LISA data calls for different data analysis approaches. Central to LISA data analysis is time-delay interferometry (TDI), a numerical procedure which drastically reduces otherwise overwhelming laser frequency noise. This procedure is not unique and gives rise to multiple TDI variables. LISA data analysis is usually performed on subsets of TDI variables which form a basis, e.g. Michelson variables (X, Y, Z). We investigate a less standard TDI variable, denoted κ, which depends on two parameters (β, λ). For *any* GW source located at sky position $(\beta_\star, \lambda_\star)$, the TDI variable κ has the singular property of canceling GW signal when (β, λ) tend to $(\beta_\star, \lambda_\star)$. This TDI variable has been briefly discussed in the LISA literature [1,2,3], but on theoretical grounds. In order to assess the applicability of this property to LISA data analysis, we evaluate κ's response to two types of sources: GBs and MBHBs. First, we conduct a thorough study on GBs evaluating κ's sensitivity to changes in GB's parameters such as sky position and frequency. Second, moving towards more realistic applications, we proceed to a similar study on MBHBs. In fact, κ could be used to rapidly determine the sky location of a GW source in a model agnostic manner or as veto to distinguish transient GW sources from instrumental glitches.

References

[1] Massimo Tinto and Shane L. Larson. Lisa time-delay interferometry zero-signal solution: Geometrical properties. Phys. Rev. D, 70:062002, Sep 2004. 10.1103/PhysRevD.70.062002.
[2] K. Rajesh Nayak, S. V. Dhurandhar, A. Pai, and J.-Y. Vinet. Optimizing the directional sensitivity of lisa. Phys. Rev. D, 68:122001, Dec 2003. 10.1103/PhysRevD.68.122001.
[3] Jean-Yves Vinet. Physical and algebraical models of lisa. Unpublished, 2007.

Session 2 / **9**

Prototyping a LISA Global-fit Pipeline

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The LISA observation band is expected to be populated with various gravitational wave signals overlapping in time and frequency, making the individual treatment for each source impossible.
We present a global-fit pipeline to disentangle the merging massive black hole binaries (MBHB) and the inspiralling Galactic white dwarf binaries (GBs) present in the simulate one-year-long LISA data.
The pipeline consists of a kick-in step of speedy approximative MBHB signal reconstruction and an iterative Bayesian detection and parameter estimation step for GBs, MBHBs as well as inference of the noise model.

Session 1 / **10**

Non parametric representation for MBHB recovery from LISA data

Auteurs: Elie Leroy[1]; Hervé Moutarde[2]; Jerome Bobin[3]

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In the context of the LISA mission, the fast detection and recovery of MBHB (Massive Black Hole Binaries) from the LISA data is key for both the low-latency and global analysis tasks. This is especially paramount when the data are gapped or contaminated with spuritous transients such as glitches. For that purpose, we introduce an hybrid non-parametric representation of MBHBs that combines an autoencoder-based modeling of the merger with a sparse modeling of the spiralling regime to provide an accurate recovery other a long time interval. We will show how the proposed signal representation can be used for detection and reconstruction tasks on both ungapped and gapped simulated LISA data.

Session 1 / 11

Compact-Transportable Iodine Stabilized Laser Setup for LISA Mission Grounds Tests Operation

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The French activities for LISA (Laser Interferometer Space Antenna) mission include assembly, integration, validation and testing of the payload by a consortium of several partners led by CNES.
SYRTE has developed for several years a laser activity for the different tests and interferometric measures realized by the consortium. A partnership with eXail led to a major technological step in the maturation and development of a reference laser stabilized on iodine. This frequency-stabilized laser setup is compact and transportable over several hundreds of kilometer and don't need any realignment after transport.
The whole laser setup is composed of two Nd:YAG lasers operating at the nominal wavelength of LISA at 1064.49 nm. These two lasers are phase locked one to another and on a telecom reference laser at 1596.7 nm which is frequency-stabilized over a hyperfine transition of Iodine vapour at 532.245 nm. The frequency gaps between the infrared and the green ranges are bridged using second-harmonic generation and third-harmonic generation. The spectroscopic bench for the Iodine interrogation is totally monolithic and doesn't need any realignment after transport.
The whole setup has been characterized with the metrological frequency chain of the LNE-SYRTE Laboratory to ensure that the LISA Mission specifications were achieved before testing with interferometric measurement. The laser setup was transported successfully by road from SYRTE-Observatoire de Paris to LAM-Marseille in July and brought to nominal operation in just 1 hour. It has been used over several weeks for great precision interferometric measures without any intervention.
The preliminary analysis of the interferometric measurements, which lasted for more than 20h each, led to results about one order of magnitude better than the LISA Mission specification. Especially, in the high frequency band where the residual noise of the laser is predominant, sub-pm/√Hz resolution has been obtained.

Session 2 / **12**

Detectability of higher harmonics with LISA

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One of the science objectives of LISA is to probe fundamental physics. With the expected large SNR of the coalescence of SMBHB we hope to test General Relativity. Using the full IMR waveform we study the detectability of higher harmonics. With Bayesian analysis, we can discriminate models with different harmonics. Omitting harmonics not only diminishes the SNR but can also lead to biased parameter estimates. We analyze the bias for each model in a source example and quantify the threshold SNR where we can expect the parameter bias to be comparable to the statistical error. This work highlights the importance of higher modes to describe the gravitational waveform of events detected by LISA, as biases in the parameters will have a deep impact in tests of the no-hair theorem.

Session 1 / **13**

Neural density estimation for Galactic Binaries with LISA

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The future space gravitational wave detector LISA (Laser Interferometer Space Antenna) will have hundreds of thousands of Galactic Binaries (GBs) constantly present in the data stream. One of the challenging tasks from the data analysis point of view will be to estimate parameters of these GBs while disentangling them from each other and from other signals present in the data. This problem is quite often referred to as Global fit in the field of LISA data analysis. To find the posterior estimates of GBs sampling techniques are often used. However in such a challenging task sampling techniques have to rely on a carefully chosen proposals. In this paper we demonstrate how we can use Neural Density Estimators (in particular Normalising Flows) to fit for distributions and the way it can be used in making proposals. At the same time we demonstrate how these fits can be applied to the posterior density estimations and used as an alternative way to provide the results of the fits to the astronomical community.

Session 3 / **14**

Astrophysical Uncertainties in the Gravitational-Wave Background from Stellar-Mass Compact Binary Coalescences

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The astrophysical Stochastic gravitational-wave backgrounds (SGWB) results from the superposition of numerous individually unresolved gravitational-wave (GW) signals. In this talk, I will present different ways of modelling the populations of stellar-mass compact binary coalescence (CBC) that source this background. I will discuss the use of population synthesis models to estimate the expected rate and properties of CBC. I will also show how these predictions are used to calculate the resulting SGWB amplitude and spectral shape, and what are the main astrophysical uncertainties on this background. Finally, I will discuss the prospects for detecting the SGWB with current and future gravitational-wave detectors.

Session 2 / **15**

Spacetime-Symmetry Breaking and the Generation of Gravitational Waves

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Recently, the search for departures from the symmetries of General Relativity has received significant attention in the literature. In this talk, I outline the techniques for probing the nature of spacetime symmetries using the generation stage of gravitational waves. By using a generic effective-field theory, I show our solution scheme of the modified Einstein equations and I write down the the first Post-Newtonian corrections, which includes contributions from the spacetime-symmetry breaking terms. Focusing on the gravitational two-body problem, I write down a simple toy solution, and it becomes clear that in contrast to General Relativity, the monopolar and dipolar contributions are non-vanishing. We comment on the detectability of such signals by the LISA space mission, which has high signal-to-noise galactic binaries well inside its predicted sensitivity band.

Nouvelles de la mission / **16**

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Nouvelles de la mission / **17**

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Nouvelles de la mission / **18**

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Nouvelles de la mission / **19**

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Carrières scientifiques / **20**

Les métiers de chercheur

Carrières scientifiques / **21**

Les métiers de l'ingénieur

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