

LISA-Spain Meeting 2025

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Book of Abstracts

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Invited talks / 1**Discovering Primordial Black Holes with LISA****Author:** Juan Garcia-Bellido^{None}

I will review the LISA PBH projects [Living Rev.Rel. 28 (2025) 1]

Contributed talks / 3**Tensor Backreaction in Chromo-Natural Inflation Systems: Evolution and Signatures****Authors:** Ema Dimastrogiovanni^{None}; Matteo Fasiello^{None}; Alexandros Papageorgiou^{None}; Cristóbal Zenteno Gatica¹¹ *IFT UAM/CSIC*

In the context of axion inflation coupled with $SU(2)$ gauge fields, commonly called chromo-natural inflation, the gauge fields' interaction with the axion acts as an extra friction term. Aside from making inflation last more e-folds of evolution, this friction also sources the scalar and tensor sectors for the perturbations, generating a particular gravitational wave signal along with curvature perturbations. On the chromo-natural evolution, this axion-gauge interaction generates a strong backreaction from the gauge tensor sector to the background evolution. This build-up to a strong backreaction regime which is independent of the potential and almost unavoidable (unless there is severe fine-tuning of the system's parameters). The effect of this backreaction leads to a particular evolution of the gauge VEV, which passes through a period of large curvature perturbations generation to reach a recently described, well-defined, new attractor evolution. In this work, we studied the most general scenarios, which show compatibility between the CMB constraints and the evolution from a weak to a strong backreaction regime. Additionally, we consider a pure natural potential for our numerical solver of the system. We also examine the gravitational wave signal (both direct and scalar-induced) and the PBH production generated due to this particular inflationary evolution.

Contributed talks / 4**A hybrid time-domain approach to the LISA response: performance and applications****Authors:** Jorge Valencia¹; Sascha Husa²¹ *University of the Balearic Islands*² *Institute of Space Sciences and University of the Balearic Islands*

We address the challenge to evaluate the response of the Laser Interferometer Space Antenna (LISA) in an accurate and computationally efficient way.

Without approximations, the full LISA response is computationally expensive and traditional approaches, such as the long-wavelength approximation, accelerate the response calculation at the cost of reducing accuracy at high frequencies. Here we introduce a novel hybrid time-domain response for LISA, that balances computational efficiency and accuracy across the binary's evolution. Our method implements a fast low-frequency approximation using central finite differences during the early inspiral—where most binaries spend most of the time in the sensitive frequency band of LISA—while reserving the computationally intensive full-response calculations for the late inspiral, merger, and ringdown phases. This hybrid approach supports CPU and GPU implementations, TDI generations 1.5 and 2.0, and flexible time-delay complexity, and has potential to accelerate parts of the global fit, and reduce power consumption.

As an application we present parameter estimation results using state-of-the-art phenomenological waveform models for LISA, which include orbital eccentricity, and the oscillatory and memory parts of the (2,0) spherical harmonic. Additionally, we evaluate the low-frequency response efficacy in early-warning pipelines by performing inspiral-only Bayesian inference.

Contributed talks / 5

A Hamiltonian approach to Schwarzschild master functions

Authors: Andrés Mínguez-Sánchez¹; Carlos F. Sopuerta²; GUILLERMO ANTONIO MENA MARUGAN³; MICHELE LENZI⁴

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The study of black hole perturbations is essential for understanding the final stages of compact object mergers. In this talk, we will explore perturbations of the Schwarzschild model from a different perspective: the Hamiltonian formalism, in contrast with the commonly used Lagrangian approach. This framework not only reproduces the well-known dynamical results but also sheds new light on the phase-space structure and the symmetries of polar and axial modes. Moreover, it provides a unified treatment of both the interior and exterior of the black hole, while offering a more direct path toward a quantum analysis of these perturbations.

Contributed talks / 6

LISA's Potential to Test the Kerr Hypothesis: Symmetry-Breaking Effects in Extreme-Mass-Ratio Inspirals

Author: Pablo F. Muguruza¹

Co-author: Carlos F. Sopuerta²

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Extreme-Mass-Ratio Inspirals (EMRIs) are one of the main sources of gravitational waves in the low-frequency band, where space-based detectors like LISA will operate. These systems consist of a stellar-mass compact object (sCO), known as the secondary object—typically a neutron star or a stellar-mass black hole—orbiting a massive black hole (MBH), the primary, in an evolutionary phase dominated by gravitational-wave emission. Due to their high precision as gravitational-wave sources, EMRIs provide a powerful framework in which to perform fundamental physics studies, such as probing the nature of the primary object and checking whether it corresponds to a Kerr black hole or a more exotic compact object.

In this work, we take advantage of the rich multipolar structure of self-gravitating bodies beyond the constraints imposed by General Relativity for black holes. We analyze the impact of gravitational radiation on generic orbits around a primary object modified by an arbitrary mass quadrupole and its non-axisymmetric component, as well as a mass octupole and its non-axisymmetric component, at leading post-Newtonian order and linear order in the mass ratio.

For this study, we use the Analytic Kludge waveform model and perform parameter estimation via Fisher analysis for our extended parameter space. We evaluate how accurately LISA will constrain the non-axisymmetric mass quadrupole and octupole moments, providing insights into the detector's ability to detect symmetry-breaking effects. This analysis will shed light on LISA's potential to probe deviations from the Kerr hypothesis.

Contributed talks / 7**From the interior to the exterior of a nonrotating black hole: extension of a vacuum state.****Author:** ALVARO TORRES-CABALLEROS¹¹ CSIC

Black holes provide a natural arena to probe quantum effects in strong gravity, yet there remain many open questions about their interiors. We study a scalar field inside a nonrotating black hole and show how interior vacua can be extended to the exterior. As an example, we analyze a non-oscillating vacuum obtained by asymptotic Hamiltonian-diagonalization. The extended vacuum state reproduces the expected large-distance decay of fields in flat or asymptotically flat spacetimes, provided infrared modes are controlled. These results represent a first step toward potential applications to black hole perturbations and the study of quasinormal modes in the light of proper quantum field theory.

Contributed talks / 8**Distinguishing Galactic Compact Binaries in LISA's Observations****Authors:** Panagiota Kolitsidou¹; Hannah Middleton²; Alberto Vecchio²¹ *University of the Balearic Islands*² *University of Birmingham*

The Laser Interferometer Space Antennae (LISA), a joint ESA-NASA mission set to launch in 2035, will revolutionise our understanding of gravitational waves, targeting a frequency range of 0.1 mHz to 1 Hz. Among its many observational challenges, one key question is whether Galactic compact binaries composed of black holes and neutron stars can be distinguished from the abundant double white dwarf binaries that are expected in the same frequency band. In this study, we perform a mock analysis of 300 binary systems consisting of black holes and neutron stars. By recovering the system masses from fiducial gravitational wave signals, drawn from an astrophysically motivated Galactic population, we explore the feasibility of distinguishing these systems from the larger population of Galactic double white dwarfs. Our results provide insight into the potential of LISA to resolve these systems, contributing to the mission's capability to discern astrophysical populations and advance our understanding of compact binary evolution in the Milky Way.

Contributed talks / 9**Massive Black Hole Binary sub-unit activities in the LISA DDP****Author:** Antoni Ramos-Buades¹¹ *University of the Balearic Islands*

In this talk I will provide an overview of the activities of the "Massive Black Hole Binary" sub-unit in the Distributed Data Processing Center (DDPC) for LISA, specifically focusing on the work done in preparation for the upcoming Mojito mock data challenge (MDC) as well as the planned activities in the subunit for the upcoming LISA MDCs.

Invited talks / 10**Testing beyond-GR physics with black hole mergers****Author:** Daniela Doneva¹¹ *University of Valencia*

The gravitational wave observations of the inspiral, merger, and ringdown of binary black hole coalescence are a powerful tool to test GR. It can probe for example the presence of additional polarizations, additional channels for energy emission, and deviations from the Kerr black hole quasinormal mode spectrum. Based on numerical relativity simulations in modified gravity, we will discuss the prospects and the limitations of testing strong gravity with present and future black hole merger observations with LISA.

Contributed talks / 11**The Strong Scalar Backreaction in non-Abelian Axion-Gauge Inflation****Author:** Mattia Cielo¹¹ *University of Naples & IFT*

Chromo-natural inflation (CNI), coupling a pseudo-scalar axion-inflaton to $SU(2)$ gauge fields, supports interesting signatures—from chiral primordial gravitational waves to large tensor non-Gaussianities and primordial black holes.

In its spectator variant (SCNI), the Chern-Simons coupling between axion and gauge sectors impacts observables even if the axion does not drive inflation. A spectator axion may help alleviate tensions with CMB observations. Crucially, in the SCNI context, the evolution of the gauge mass parameter m_Q may lead to a robust scalar backreaction, shaping the background evolution and enhancing the primordial gravitational wave spectrum.

I present the first numerical study isolating and analyzing the impact of scalar backreaction on the background equations, revealing novel effects on the gravitational wave spectrum and providing new insights into the model's dynamics.

The detectability of the corresponding signatures is also briefly discussed.

Contributed talks / 12**Towards a fast and reliable global fit with Sequential Neural Likelihood****Author:** Ivan Martin Vilchez¹**Co-author:** Carlos F. Sopuerta²¹ *Institute of Space Sciences (ICE, CSIC and IEEC)*² *Institute of Space Sciences of the Spanish National Research Council (ICE, CSIC)*

The LISA mission will detect many overlapping gravitational wave signals, making data analysis particularly challenging. Due to the high dimensionality of the problem, the global fit of all sources using traditional Bayesian methods is expected to be by far the most computationally intensive task

that the LISA Distributed Data Processing Centre (DDPC) will perform. As such, there is interest in accelerating the global fit using alternative algorithms.

We investigate Sequential Neural Likelihood (SNL) as a simulation-based approach to learn likelihood surrogates from data. On data containing a Massive Black Hole Binary (MBHB) merger and simplified noise, we demonstrate that that SNL can provide flexible posterior estimation, in a manner that should scale well and remain reliable as realism is increased.

Invited talks / 13

LST Status Update / EMRI Waveforms

Author: Anna Heffernan¹

¹ *University of the Balearic Islands*

Extreme-Mass Ratio Inspirals (EMRIs) are a key source for the future space-based gravitational wave detector, LISA. In this talk, I will give a review of EMRIs and the self-force method, the leading technique in EMRI-waveform modelling. In particular, I will give a current status update, outline key challenges and exciting new prospects.

Contributed talks / 14

Detecting DM Decay into Gravitons: Theory and Forecasts

Author: Álvaro Cendal¹

¹ *Universidad Complutense de Madrid & IPARCOS*

Dark matter may not be completely stable, and its decay could lead to new signatures in the form of gravitational waves. In this talk I will present model-independent predictions for the stochastic gravitational wave background produced by dark matter decaying into gravitons. Using this framework, I forecast the sensitivity of current and upcoming gravitational wave detectors to these signals.

Contributed talks / 15

Kinematic anisotropies in LISA

Author: Jacopo Fumagalli¹

¹ *ICC - Barcelona U.*

I will discuss ongoing efforts on exploiting kinematic anisotropies in LISA for gravitational-wave background reconstruction.

Contributed talks / 16

Subtraction of Correlated Low-Frequency Noise Induced by a Magnetic Field Simulator for In-Orbit Experiments of Magnetic Measurements

Author: Cristian María-Moreno¹

Co-authors: Ignacio Mateos¹; Guillermo Pacheco-Ramos²; Francisco Rivas³; María-Ángeles Cifredo-Chacón¹; Ángel Quirós-Olozábal¹; José-María Guerrero-Rodríguez¹; Pablo Cárdenas-Fernández¹; Julen Morillas-Alcarazo¹; Nikolaos Karnesis⁴

¹ *University of Cadiz*

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⁴ *University of Thessaloniki*

In this work, we present a Low Earth Orbit (LEO) magnetic field simulator for technology demonstrators of future space-born gravitational wave detectors. The scientific unit used during the tests is a magnetic experiment system conceived to demonstrate the in-orbit performance of Anisotropic Magnetoresistance (AMR) sensors onboard nanosatellites. As part of the H2020 and Horizon Europe Programmes, and with the participation of the European Space Agency (ESA), this experiment will undergo functional characterization in orbit. A key difficulty, however, lies in disentangling the instrument's intrinsic noise from the low-frequency magnetic disturbances caused by the Earth's field along the orbit. To address this, the present work seeks to reproduce the expected magnetic environment in LEO and develop subtraction strategies to remove spurious contributions from the scientific data. Long-term magnetic variations are simulated on ground using a three-axis Helmholtz coil system, while a Fluxgate Magnetometer (FGM) provides reference measurements of the applied fields. Correlating these references with the payload's output enables effective subtraction of environmental effects. Validating this approach is an essential step towards a reliable in-orbit characterization of magnetic measurement systems in space for future missions requiring low magnetic noise levels and long integration times.

Contributed talks / 17

Magnetic diagnostics on-board LPF

Author: Daniel Serrano Rubio¹

¹ *IEEC*

LISA Pathfinder was a mission designed to test key technologies required for gravitational wave detection in space. Magnetic forces have an important impact on the instrument sensitivity in the low frequency regime below the millihertz. A precise characterization of the magnetic properties of LISA Pathfinder free falling test-masses is of special interest for future gravitational wave observatory in space. We report on the magnetic injection experiments performed throughout LISA Pathfinder operations. We show how these experiments allowed a high precision estimate of the instrument magnetic parameters. The remanent magnetic moment was found to have a modulus of $(0.245 \pm 0.081) \text{ nAm}^2$, the x-component of the background magnetic field within the test masses position was measured to be $(414 \pm 74) \text{ nT}$ and its gradient had a value of $(-7.1 \pm 2.1) \mu\text{T/m}$. The test mass magnetic susceptibility was measured to be $(-3.35 \pm 0.15) \times 10^{-5}$ in the low frequency regime. Finally, magnetic forces couple to the test mass motion, introducing a contribution to the relative acceleration noise between the free falling test masses. Our results set the magnetic-induced acceleration noise during the February 2017 noise run of $0.25^{+0.15}_{-0.08} \text{ fm s}^{-2}/\sqrt{\text{Hz}}$ at 1 mHz and $1.01^{+0.73}_{-0.24} \text{ fm s}^{-2}/\sqrt{\text{Hz}}$ at 0.1 mHz. We also discuss how the non-stationarities of the interplanetary magnetic field can affect these values during extreme space weather conditions. All results are in agreement with on-ground estimates.

Contributed talks / 18

UCAnFly CubeSat Mission Status: Sub-millihertz Chip-Scale Magnetometry Moving Toward System Assembly

Authors: Julen Morillas-Alcarazo¹; Pablo Cárdenas-Fernández²; Cristian María-Moreno²; Juan Francisco Santos-Relinque^{None}; Sascha Paez-Enders^{None}; Celia Ojeda^{None}; José Manuel Tocino^{None}; María Molina-Arnica^{None}; Alejandro Cantos-López^{None}; Javier Sánchez-Márquez^{None}; Irene del Sol^{None}; Guillermo Pacheco-Ramos³; Francisco Rivas⁴; Germán León^{None}; Juan Ángel Tendero^{None}; Pablo Moreno-García^{None}; Antonia Morales-Garoffolo^{None}; Francisco Luna-Perejón^{None}; María-Ángeles Cifredo-Chacón²; José-María Guerrero-Rodríguez²; Ángel Quirós-Olozábal²; Arturo Morgado^{None}; Manuel Domínguez^{None}; Ignacio Mateos²

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UCAnFly is a multidisciplinary team born at the University of Cádiz, recognized as one of the selected projects in the third edition of ESA's *Fly Your Satellite!* programme. The team is developing a 1U CubeSat carrying the Magnetic Experiment for LISA (MELISA-II) as its primary payload: a sub-millihertz magnetometer based on Anisotropic Magnetoresistance (AMR) sensors, designed to detect magnetic field fluctuations below $10 \text{ nT Hz}^{-1/2}$ within the 0.1 mHz-1 Hz frequency range - an essential requirement for future space-based gravitational wave observatories - in Low Earth Orbit (LEO); and to increase its Technology Readiness Level (TRL).

In contrast to the traditional fluxgate magnetometers, often constrained by their size and weight, MELISA-II offers a lightweight, chip-scale solution. This innovation opens the door to replacing or complementing fluxgates in certain applications and enhancing the scientific capabilities of small satellites and large-scale space observatories alike.

MELISA-II has successfully completed its environmental qualification campaign, including an electromagnetic compatibility (EMC) test at ESA ESTEC (Noordwijk, The Netherlands), as well as thermal vacuum cycling and vibration testing at ESA ESEC-Galaxia (Transinne, Belgium). Following the completion of its flatsat integration campaign, UCAnFly is now preparing for the upcoming satellite assembly phase.

The development of MELISA-II and UCAnFly represents a unique educational opportunity, allowing university students to participate in a real space mission, under the guidance and support of the European Space Agency's Education Office.

This work presents the status of the project, highlighting both the recent milestones achieved and the forthcoming steps that will bring MELISA-II closer to its first flight opportunity.

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LISA Status and Spanish Contribution after Adoption

Invited talks / 20

Mission and Consortium overview

Invited talks / 21

SOC Overview

Invited talks / 23

Waveforms: challenges, status, and ongoing work in the Consortium and DDPC

I will summarise the challenges for developing waveform models that satisfy the requirements for LISA, and summarise the current and planned waveform activities in the LISA Consortium and Distributed Data Processing Center.

Invited talks / 24

Fundamental Physics with LISA

Invited talks / 25

Spain's Contribution to the LISA Payload: The Science Diagnostics Subsystem

In this talk, I will present the Science Diagnostics Subsystem (SDS), which constitutes the Spanish payload contribution to LISA. After outlining its motivation and architecture, I will describe its key elements: temperature sensors and actuators, low- and audio-frequency magnetometers, and a radiation monitor. I will summarise the current development status and highlight the next milestones, including the ILIADA in-orbit demonstrator mission, which will validate critical SDS technologies.