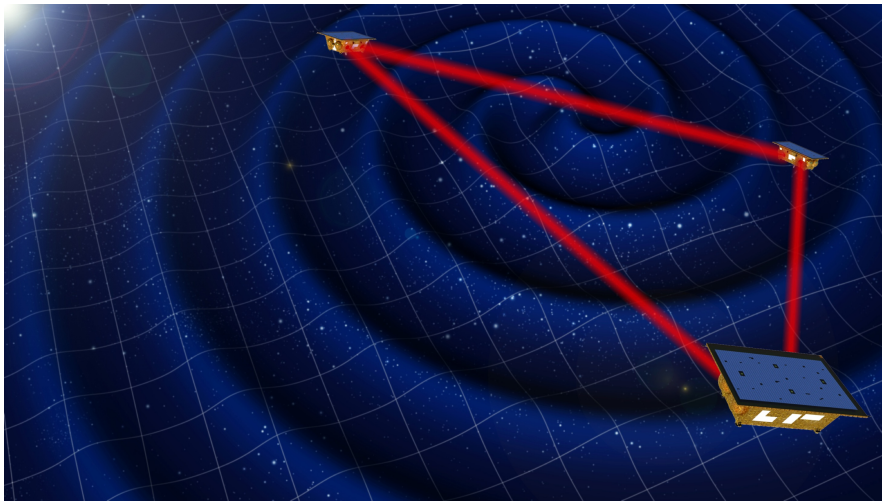
Gravitational Wave Astronomy – LISA Group

Our research focus on all aspects related to the emerging field of Gravitational Wave Astronomy

We lead the Spanish contribution to ***LISA***. We also contribute to other GW projects as the *Einstein Telescope* or *ELGAR*.



We are **core members** of the LISA Consortium, a worldwide scientific collaboration involved in space-borne GW detectors.

Scientific staff
C.F. Sopuerta - Theoretical lead (sopuerta@ice.csic.es)
M. Nofrarias - Experimental lead (nofrarias@ice.csic.es)

Management
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Postdoc
M. Lenzi
PhDs
I. Martín-Vilchez – V. Gualani – D. Serrano
Students (TFM/TFG/Internship)
M. Arqué – S. Sisteré – A. Gonzalvez – B. Bonastre – J. Morales

12+ PhDs thesis defended in the group with successful latter academic (postdoc) or industrial enrolment!

Instrument activities – LISA development

- We lead design of the **Data and Diagnostics Subsystem for LISA (Spanish contribution)**, this includes
  - the Diagnostics (thermal, magnetic, radiation) and
  - the Instrument Control Computer on-board.

- *Plan Nacional* funding (including UPC, UB, CSIC) approved for 2020-23 period, both in experimental and theoretical fronts
  - Project team: 12 staff researchers (2 Science +10 Instrument), 2 staff managers, 5 senior engineers, 4 post-docs, 3 PhD students
  - Extensive experience in space instrumentation

- Industrial contribution funded through **PRODEX** program. Proposal by **SENER + IEEC** approved by CDTI, currently in negotiation with .
  - Project team: 12 staff researchers (2 Science +10 Instrument), 2 staff managers, 5 senior engineers, 4 post-docs, 3 PhD students

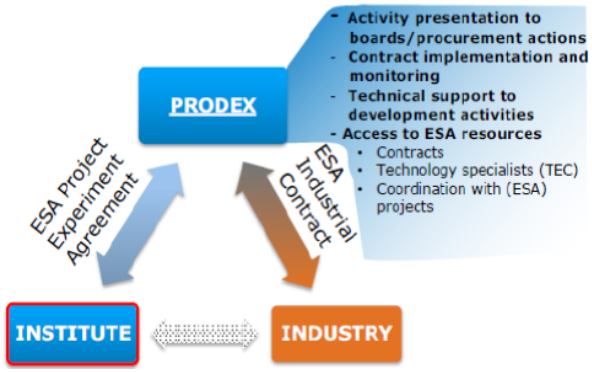
- Current industrial ROM estimation cost for phase B/C/D for **Spanish contribution to LISA is ~ 35 M**.

AGENCIA ESTATAL DE INVESTIGACIÓN

CDTI

IEEC

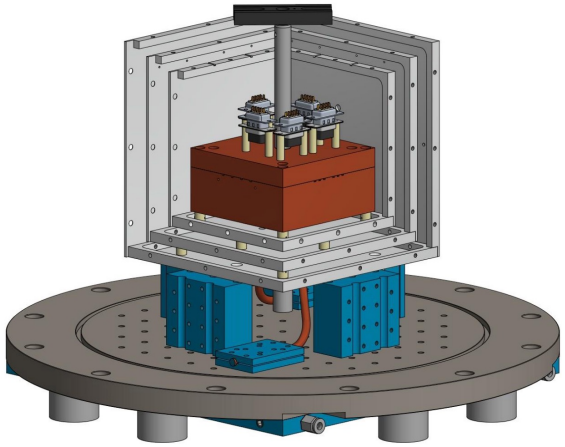
SENER Aeroespacial



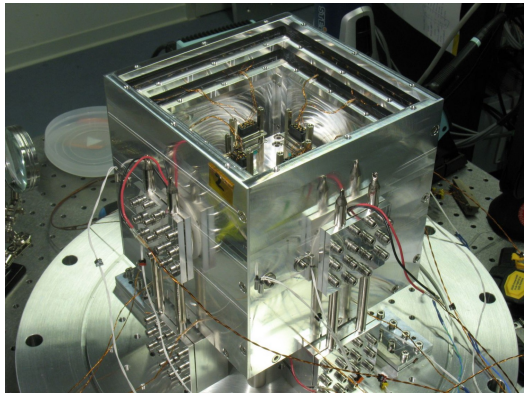
Instrument activities – temperature sensor technology development

- We are running **two ESA contracts** to develop high precision temperature measurement prototypes for space-applications using **thermistors (LETS project)** and **optical fibers (LIRA project).**
  - *in collaboration with SENER Aerospacial,*
  - *German Aerospace Agency (DLR)*

  and INESC TEC (Portugal)



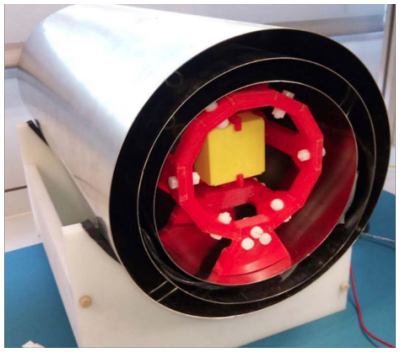
- The objectives of these activities is to develop **high precision sensors (1μK/√Hz at 1mHz)** for space-borne gravitational wave missions
  - *these technology can be exported to 3rd generation experiments on-ground*



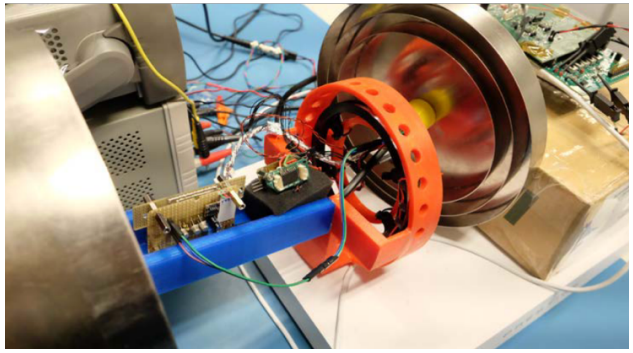
- *A crucial part is the design of an **ultra-stable test bench** that guarantees the required stability to perform measurement*
  - *essential development when facing low frequency regime*
  - *our group has a decade long expertise*

Instrument activities – magnetic sensor technology development

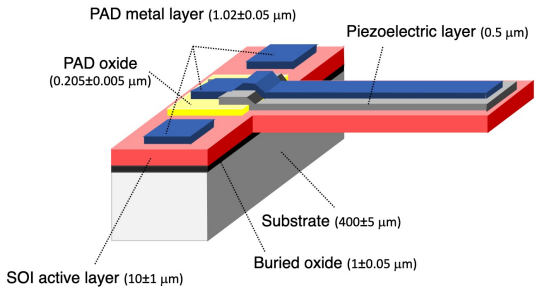
- We have developed an improved **magnetic diagnostic system (10 nT/√Hz at 1mHz)** more compact and avoiding back-action problems
  - based on **Anisotropic magneto-resistors (AMR),** solid-state, low noise magnetic sensors.
  - AMR is a compact, low-noise with no magnetic back-action



- The test bench is composed
  - three concentric **mu-metal** layers to isolate from Earth magnetic field
  - a **coil** inside to generate controlled inputs
  - a **3D printed structure** to located sensors and allow gradient estimates



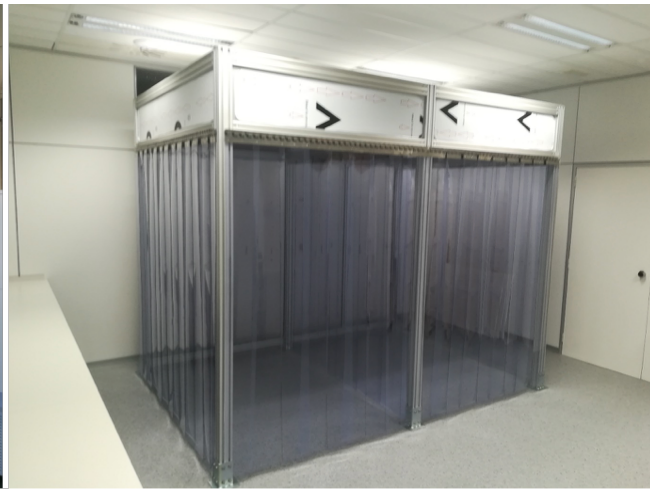
- We are developing *new magnetic sensors* based on **Microelectromechanical Systems (MELISA project)**
  - This project has been awarded **seed funding** from an internal IEEC call.

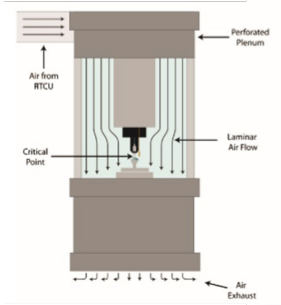


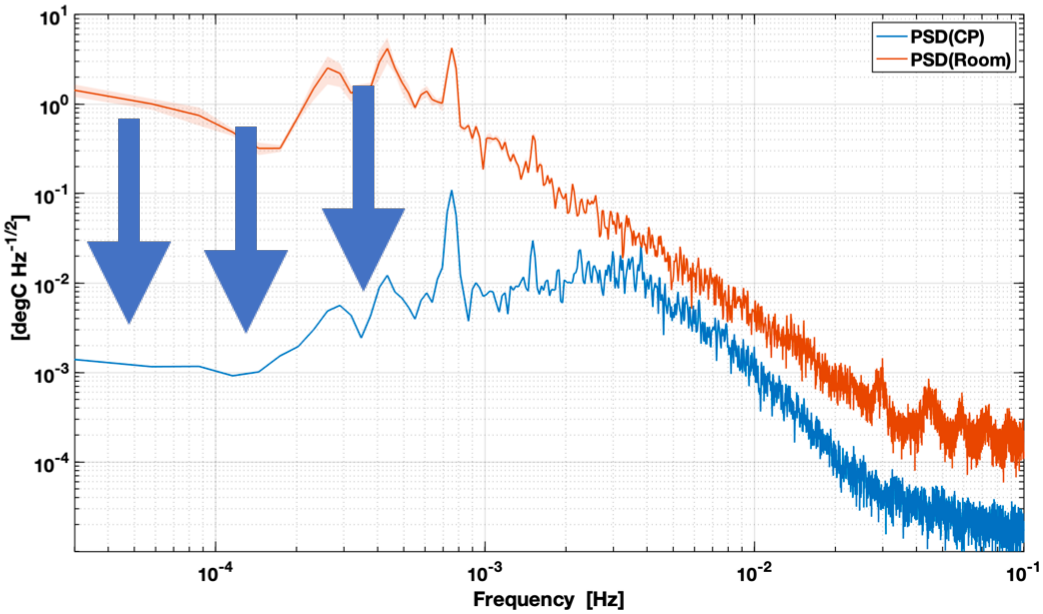
High-stability AIVT facilities

High stability temperature control facility at ICE labs

- *Facility with controlled laminar flow with ± 5mK stability.*
- *General purpose facility for AIVT*
- *Facility is installed and operative*

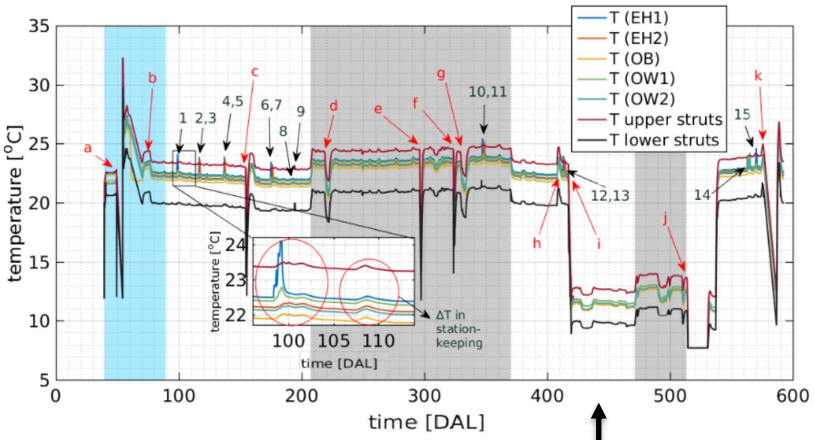


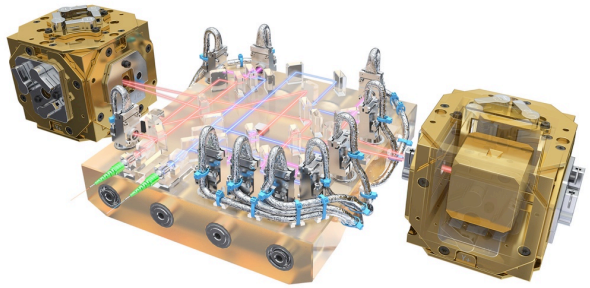




Data Analysis activities

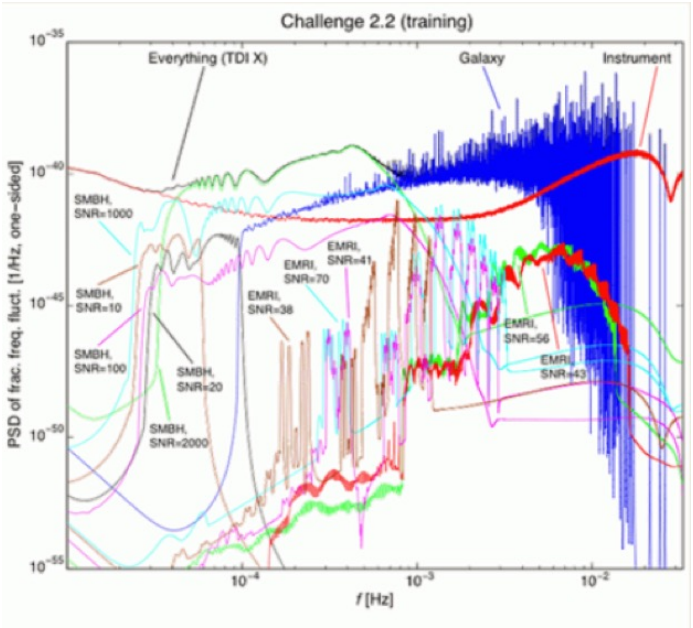
We contributed to the **mission operations and data analysis** of LISA Pathfinder (2015-17), the precursor of LISA.





Our **group led the analysis of the diagnostics sensors** during flight operations

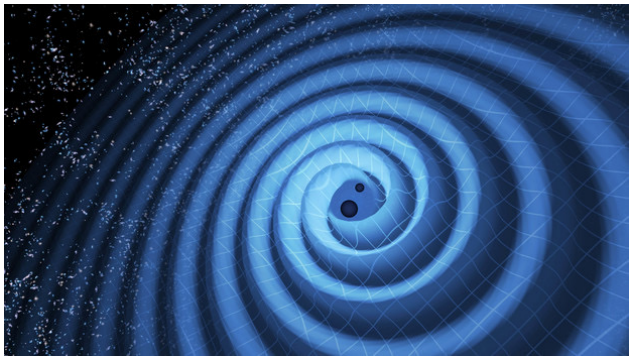
We are developing **data analysis algorithms** within the LISA Data Challenges Working Group to maximize the scientific outcome of LISA

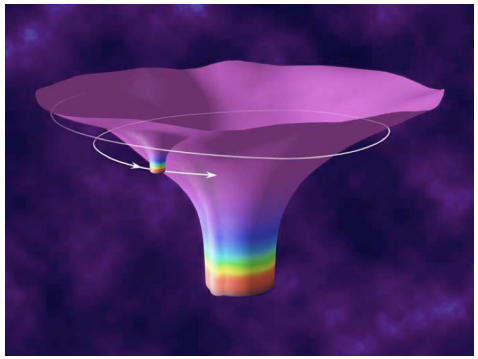


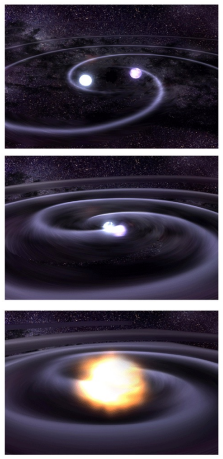
Theoretical activities

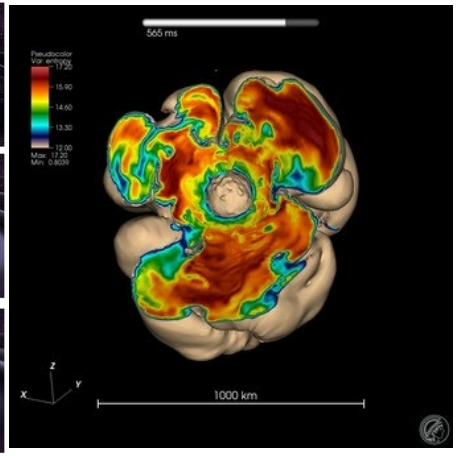
- **Modeling of the main sources of Gravitational Waves**: Using General Relativity we construct waveform models crucial for the success of the Data Analysis Algorithms. The sources include: Compact Binary Coalescence (Black Holes and Neutron Stars); the capture and inspiral of a stellar object into a Supermassive Black Hole; etc.

- **Studies for the Scientific Exploitation of Gravitational Wave Observations**: Astrophysical and cosmological studies of the event rates of different sources; consequences of the detection for the populations of stellar objects and supermassive black holes; tests of the *no-hair* conjecture for Black Holes; tests of General Relativity and alternative theories of gravity; etc.









ICE Interest in the Einstein Telescope (ET)

- **Interest for ET in Instrumentation:** Sensors for environmental control: magnetic and thermal control.
  We consider our experience in the development of precision sensor in the low-frequency regime (mHz) of potential interest in ET. We think it has synergies with the potential magnetic noise contribution, which requires high precision and low-frequency (ultra-stable) measurements.

- **Interest for ET in Theory/Data Analysis:** Compact Binary Coalescing modelling (specially for non-comparable masses); machine learning algorithms for detection and parameter estimation. Data processing infrastructures and software.

- **Other Interest at the ICE:** Neutron Star Physics (magnetars; EoS; EM counterparts; pulsars; etc); observations of intermediate-mass black holes; early-universe physics.