Laser Interferometer Space Antenna

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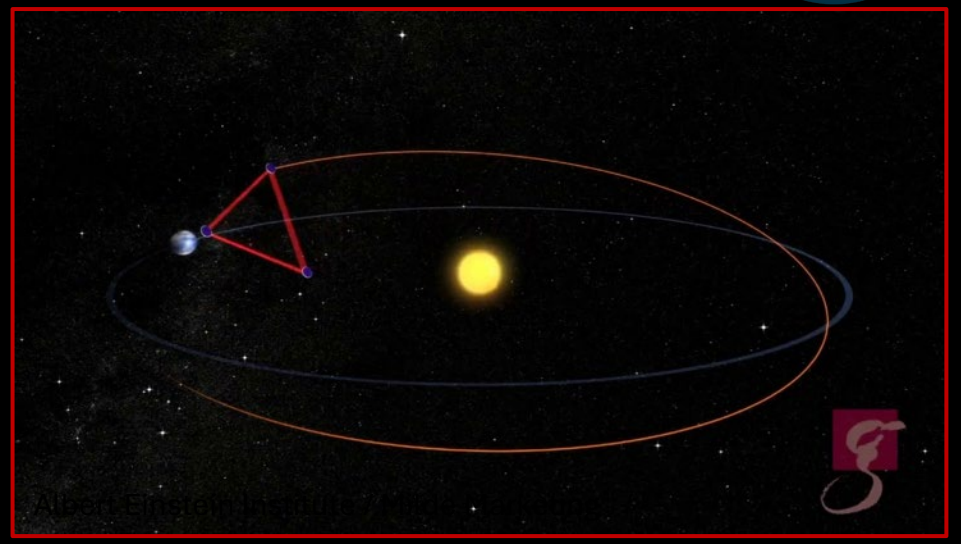
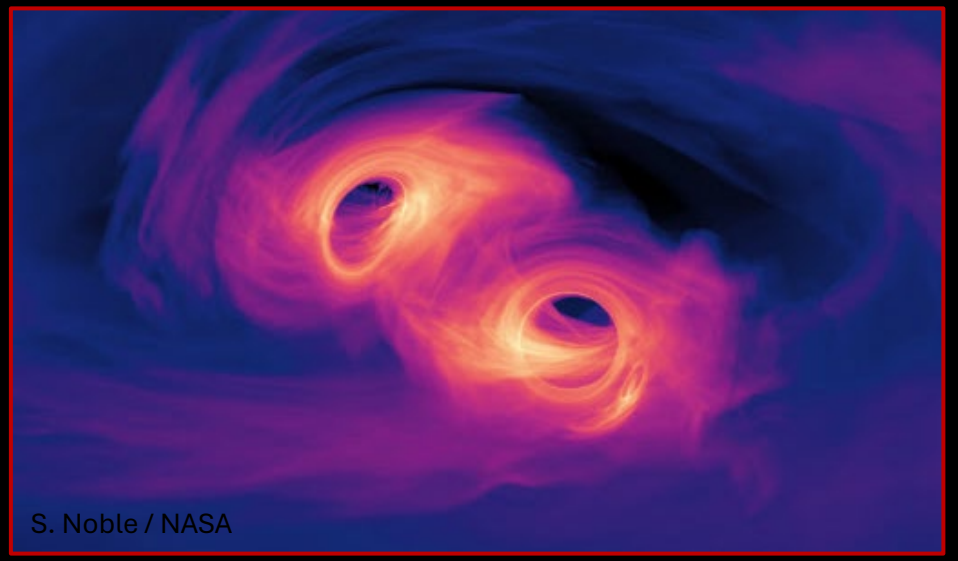
Joey Shapiro Key
U. Washington Bothell
LISA Science Team Member





NASA Gravitational Wave Science Interest Group
Summer LISA seminar series
May 29th, 2025

Talk Outline:

- What is LISA?
  - Science
  - Mission
  - Technology
- What is LISA's Status?
  - ESA
  - NASA
- What is the LISA Science Team?
  - Charge
  - Members
  - Activities

What is LISA?

Dr. Ira Thorpe

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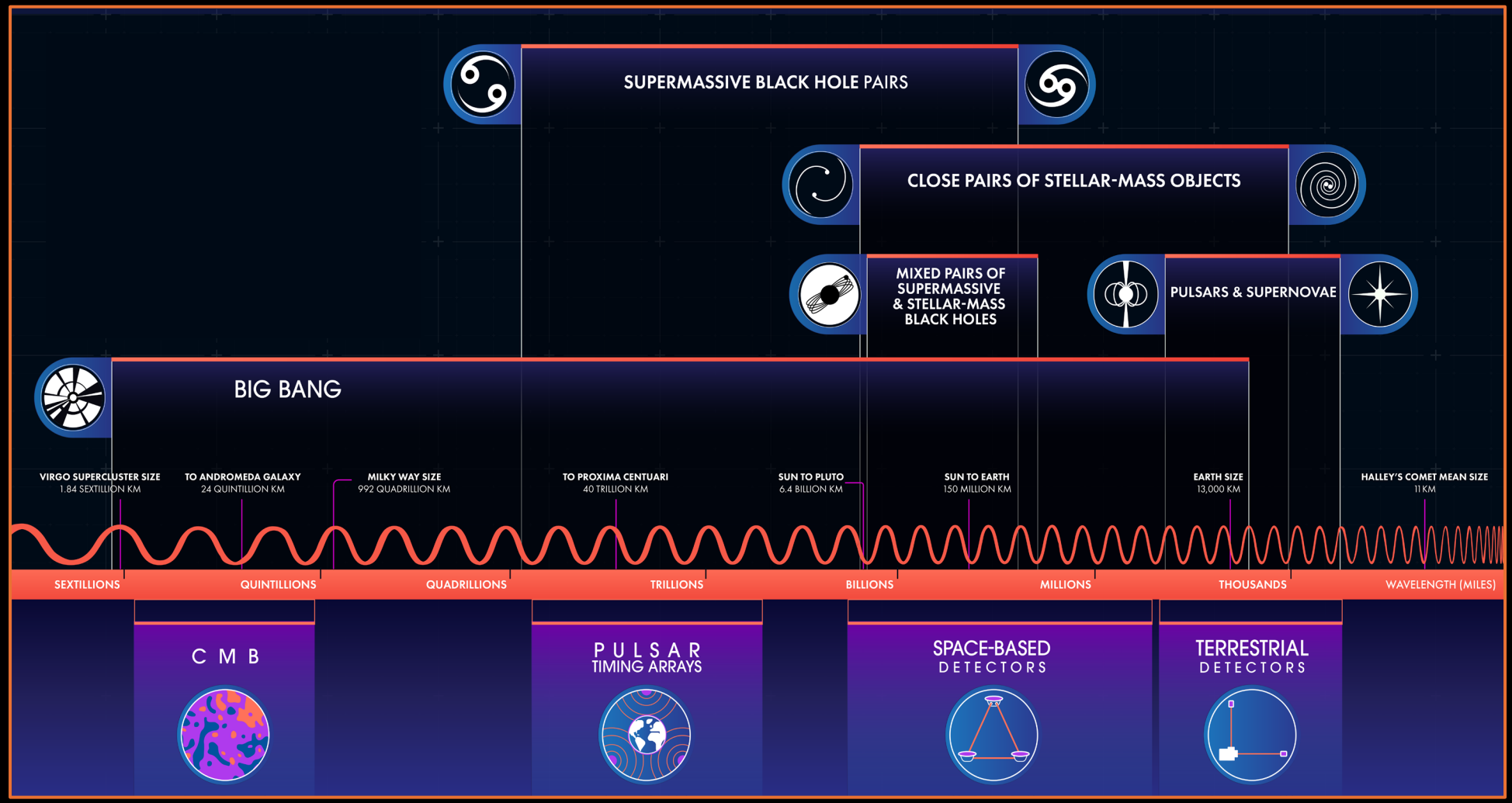
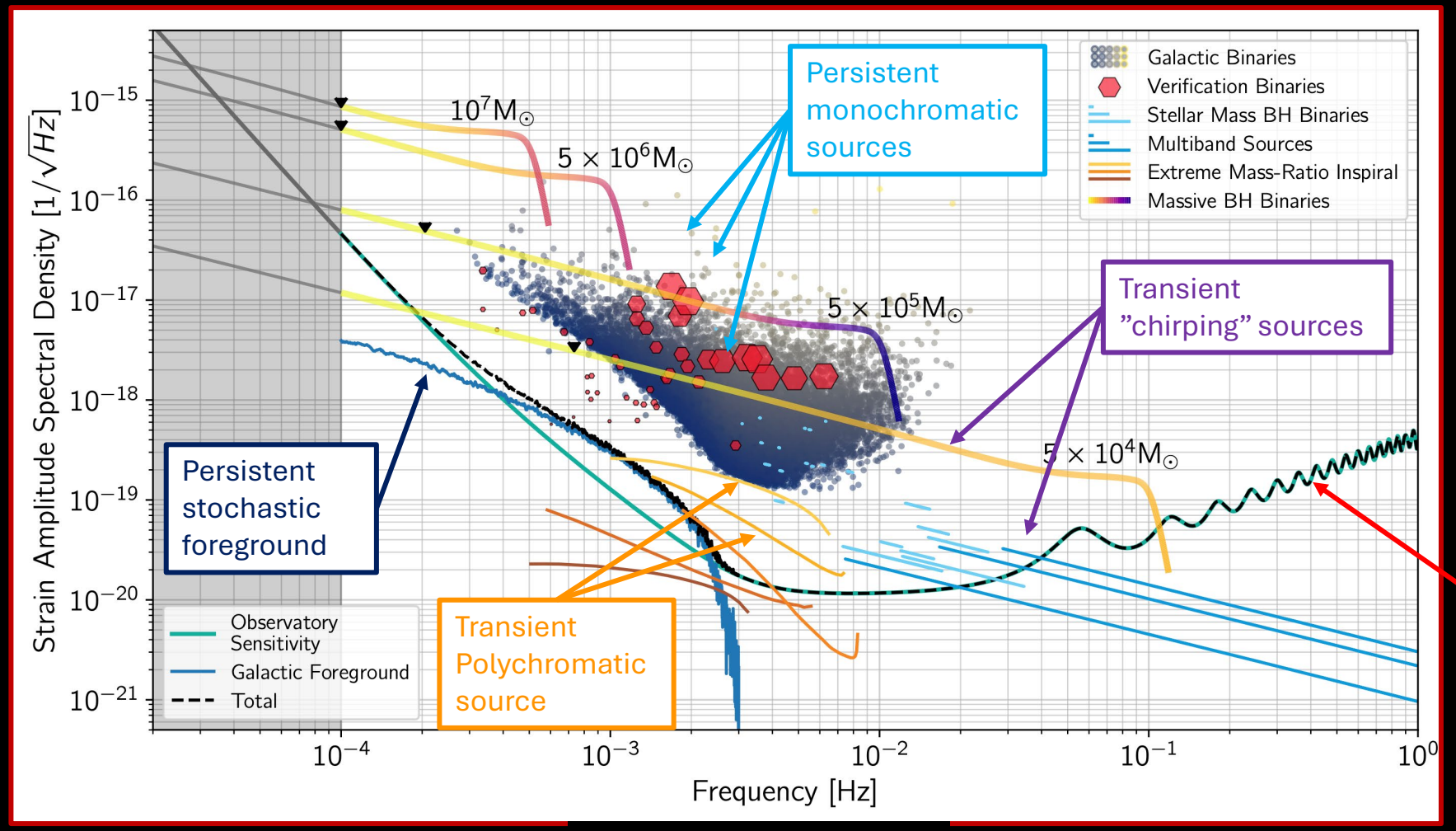
LISA Project Scientist (NASA)

The GW Spectrum

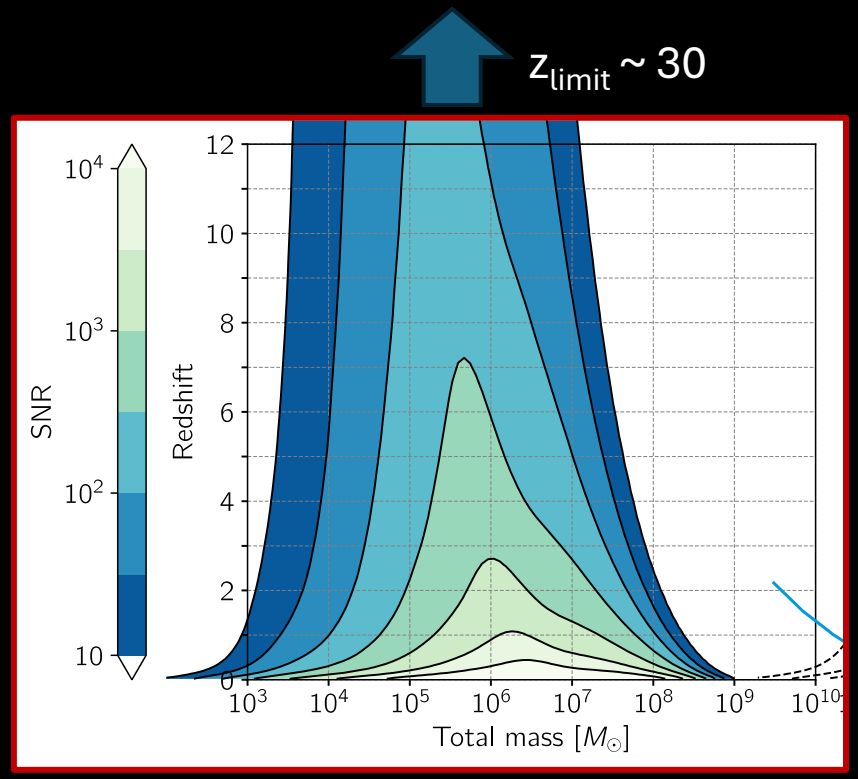
- Broad spectrum of wavelengths / frequencies
- Different astrophysical and cosmological sources in each band
- Different detection techniques required for each band



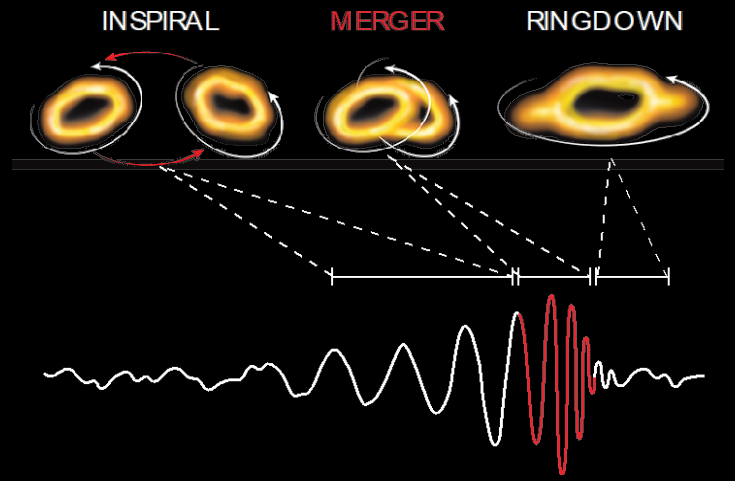
Why Millihertz? *Lots of Sources and Science!*



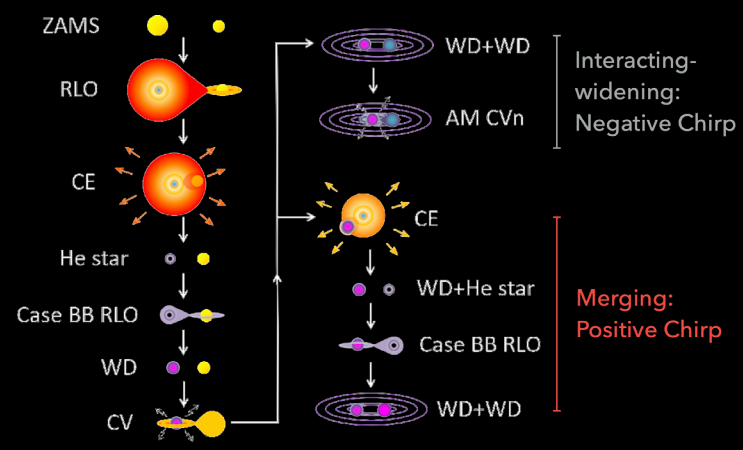
Science Highlights



Census of massive black hole mergers into the cosmic dark ages



Precision tests of GR in extreme gravitational environments



Tens of thousands of compact binary systems in the Milky Way

Formal Science Objectives

LISA SCIENCE OBJECTIVES

1. Study the formation and evolution of **compact binary stars** and the structure of the Milky Way Galaxy
2. Trace the origins, growth and merger histories of **massive Black Holes** across cosmic epochs
3. Probe the properties and immediate environments of Black Holes in the local Universe using **extreme mass-ratio inspirals** and **intermediate mass-ratio inspirals**

4. Understand the astrophysics of **stellar-mass Black Holes**
5. Explore the **fundamental nature of gravity** and Black Holes
6. Probe the rate of **expansion of the Universe** with standard sirens
7. Understand **stochastic gravitational wave backgrounds** and their implications for the early Universe and TeV-scale particle physics
8. Search for gravitational wave bursts and **unforeseen sources**

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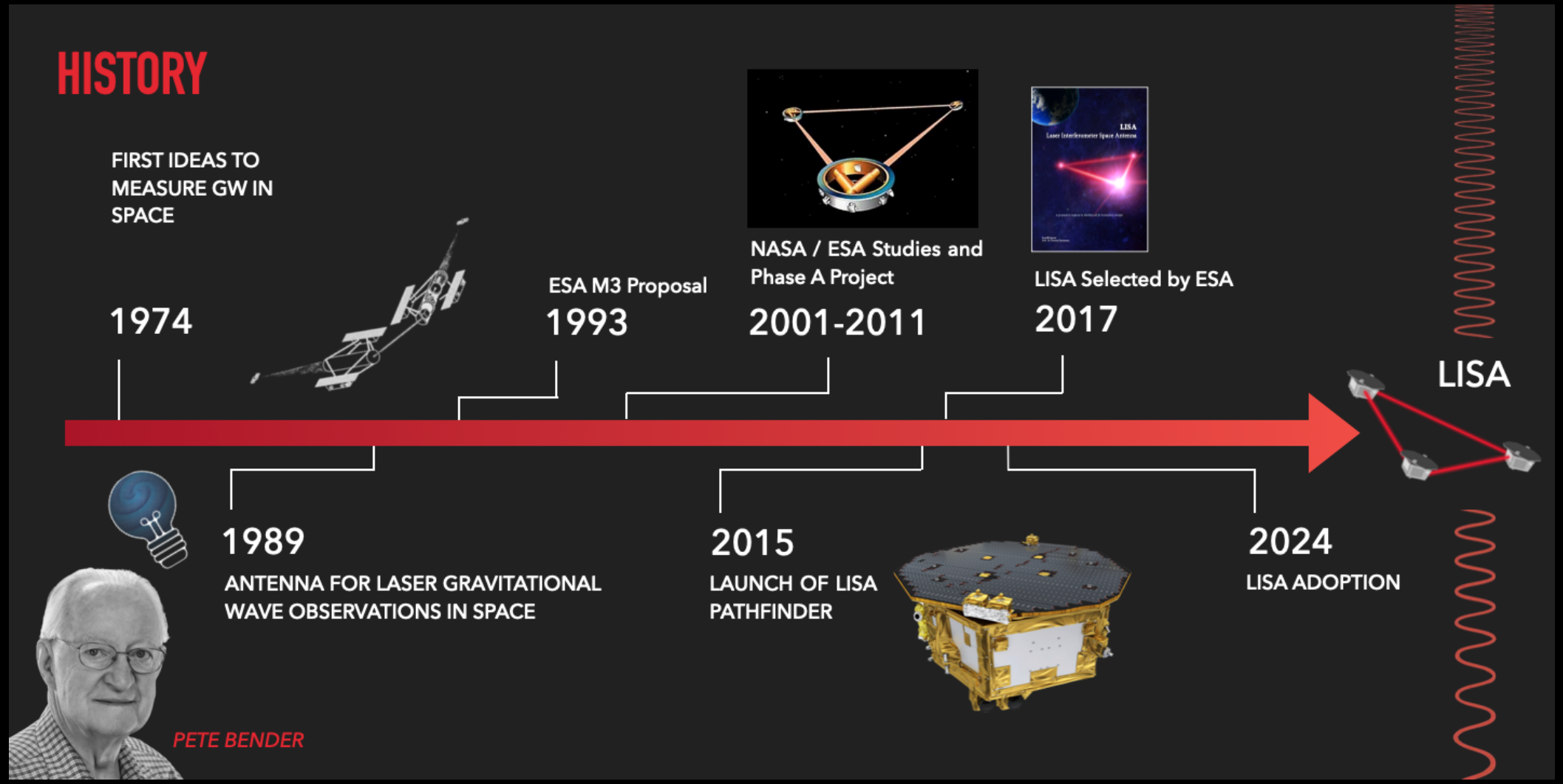
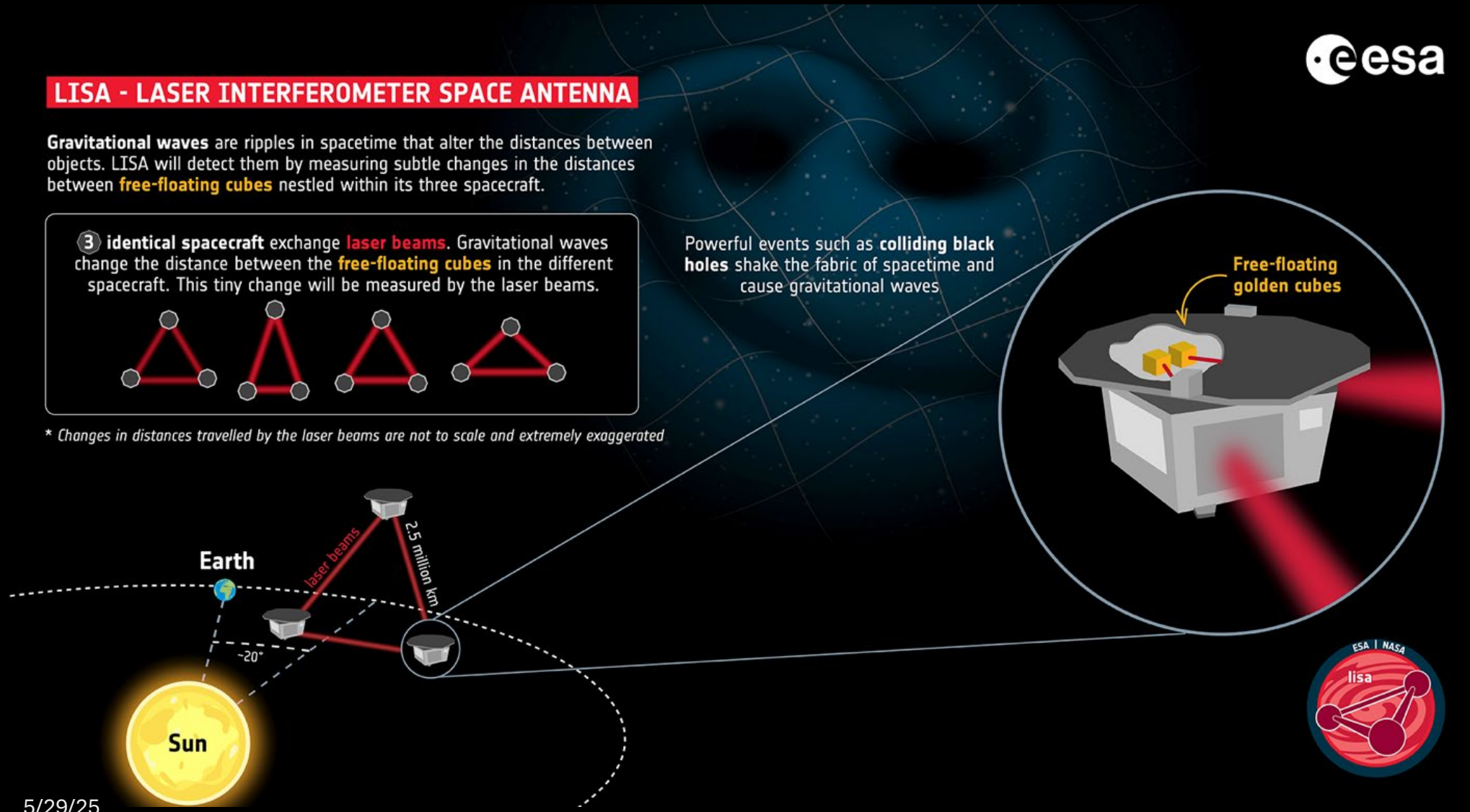
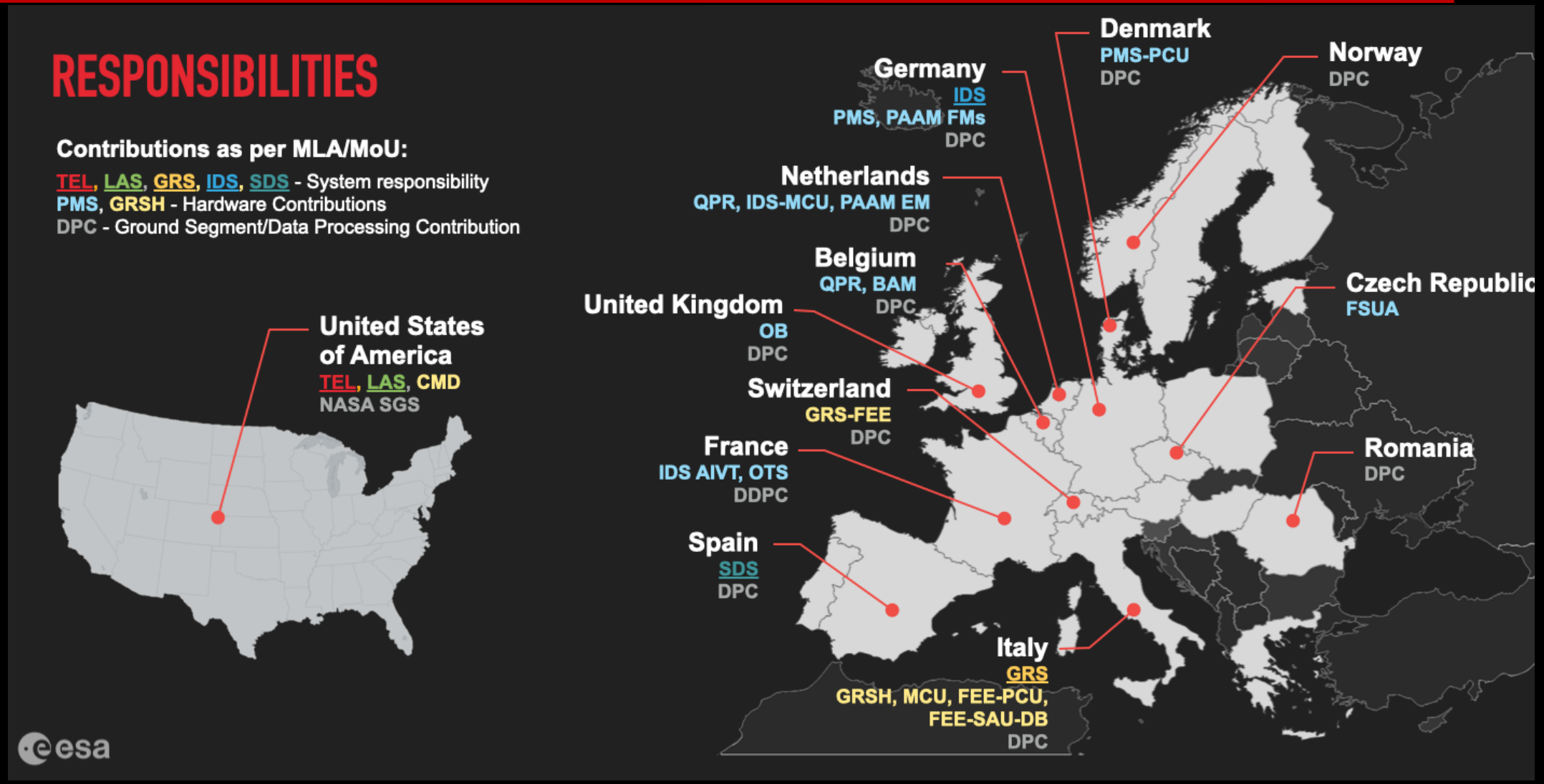
LISA Concept History



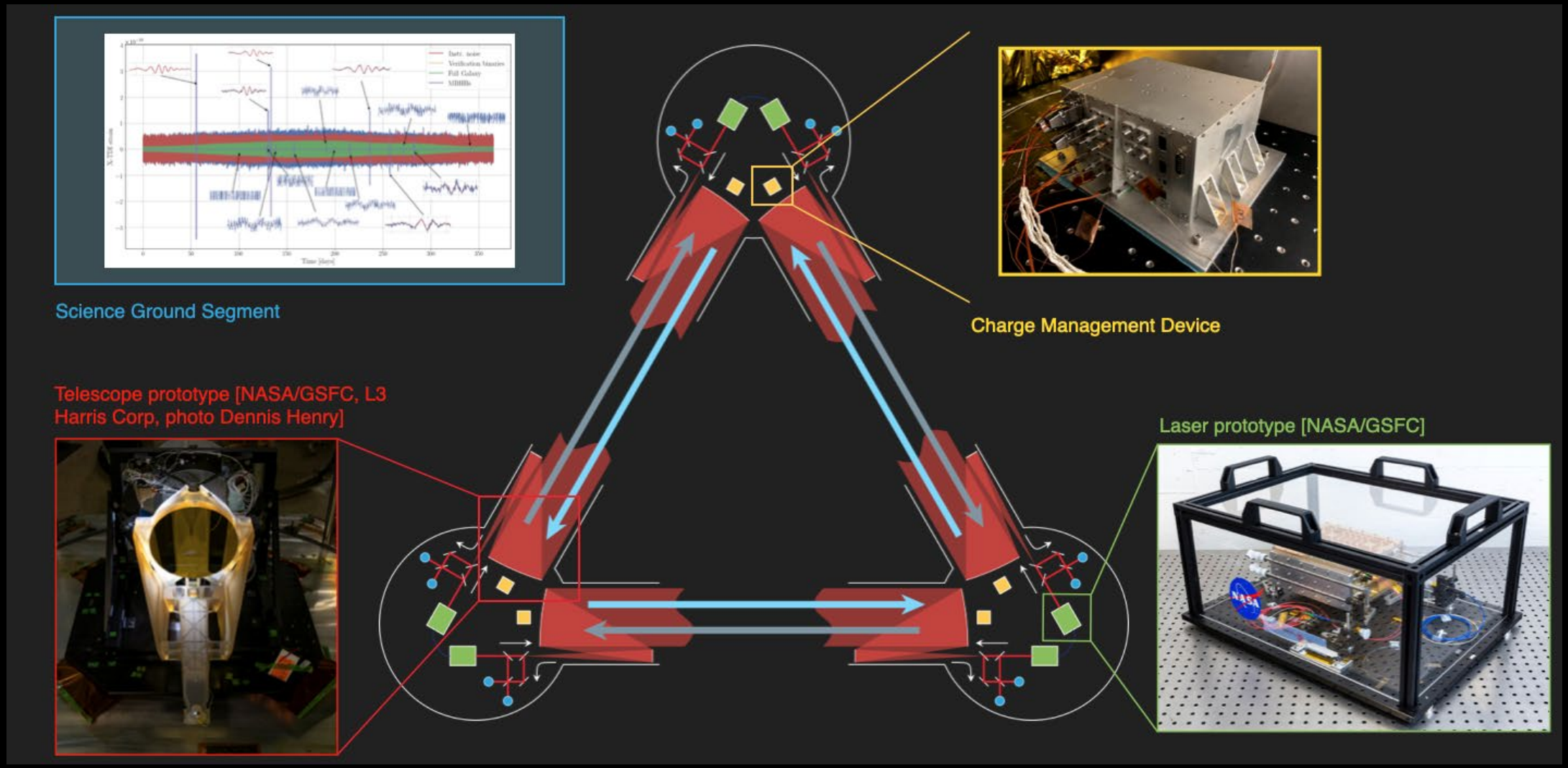
Measurement Principle



International Partnership



NASA Deliverables



Science Ground Segment – Global picture

Where is LISA?

Dr. Ira Thorpe

NASA/GSFC Code 663

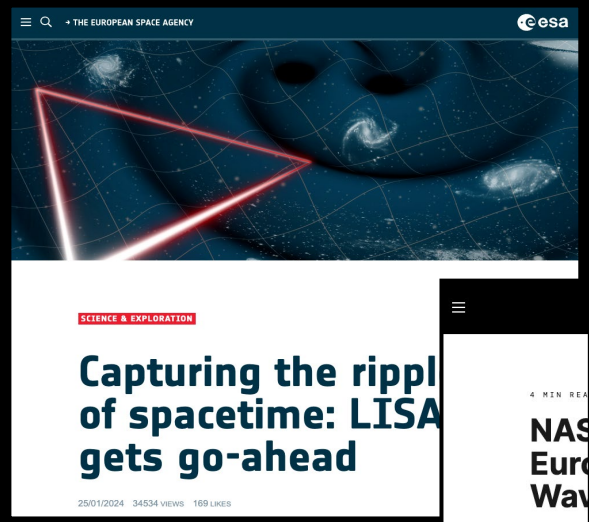
LISA Project Scientist (NASA)

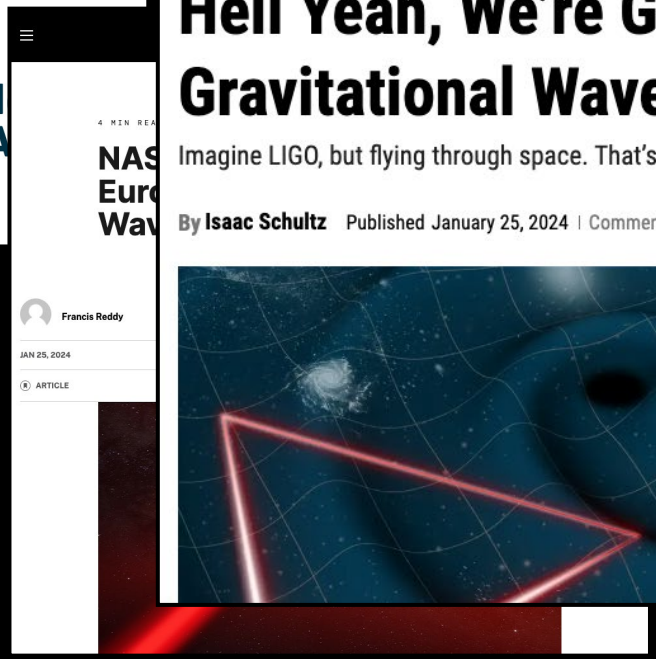
January 2024: ESA Adopts LISA

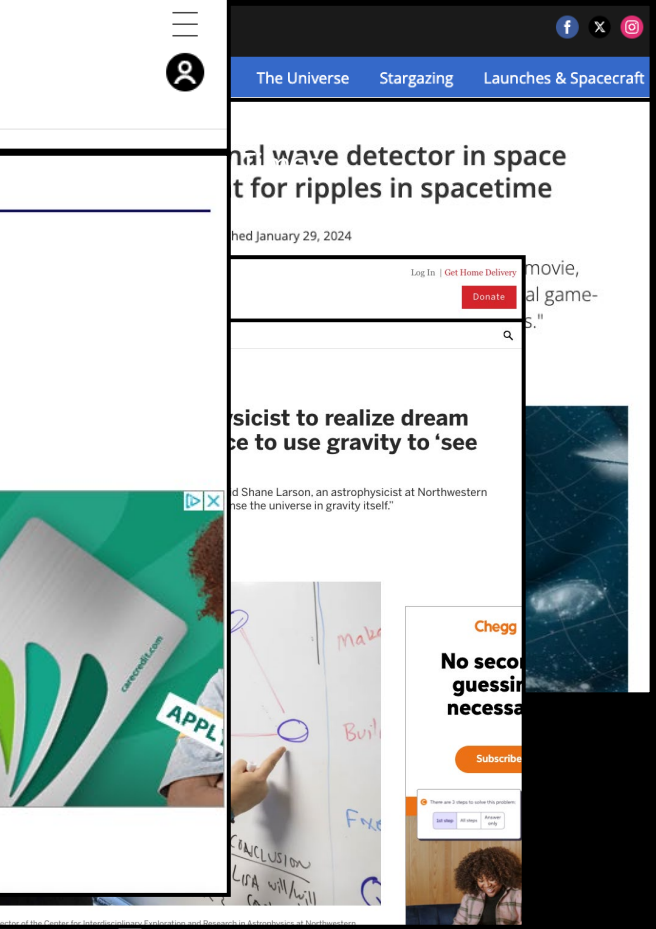
ESA

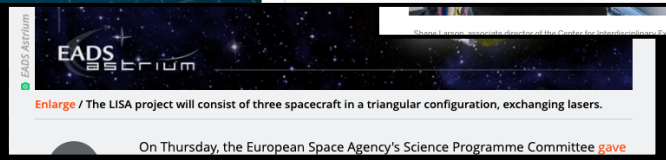
Scientific American

Space.com









ESA Highlights since Adoption

- Establish full project team
  - PM: Fillipo Marliani (PLATO)
  - PS: Nora Lützgendorf (JWST), Oliver Jennrich (LISA)
- Selected Spacecraft Prime Contractor
  - Invitation to tender released March ‘24
  - Proposals received August ‘24
  - Decision confirmed December ’24
  - Contract signed March ‘25
  - Public announcement expected June ‘25
- Worked with member states and NASA to consolidate requirements and schedule for payload contributions (“co-engineering”)
- Establish baseline performance model used to track mission performance
- Selected community science team (with NASA) - the LISA Science Team
- Signed MoU with NASA, MLA with Member States

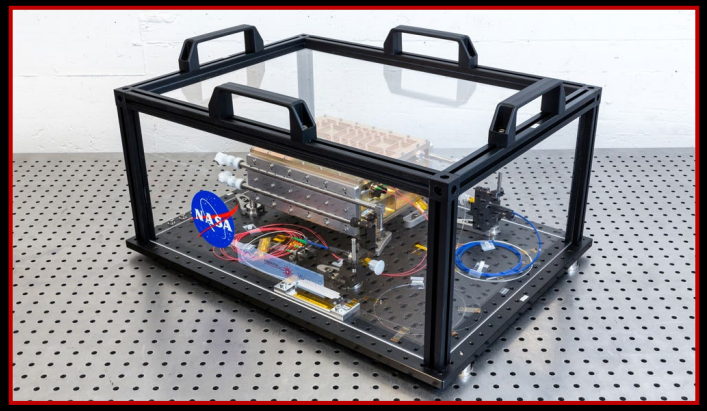
SPACESHIP!

NASA Highlights since Adoption

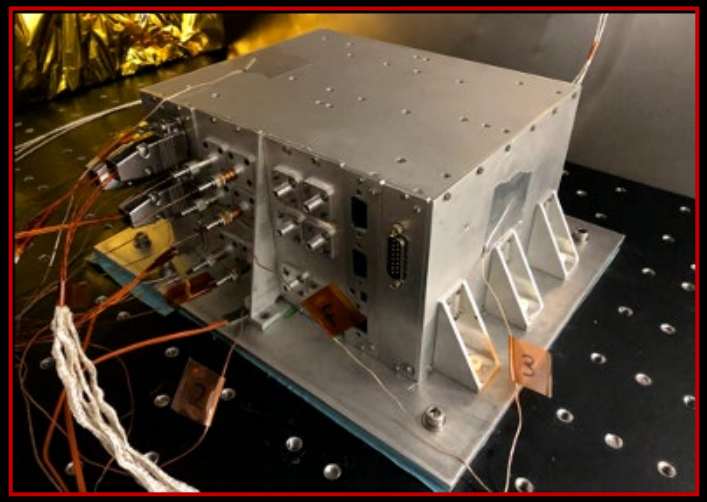
- Project Established Aug. 1, 2024
  - PM: Mark Voyton (JWST, PACE), DPM: Julie Lander (PACE)
  - PS:Ira Thorpe (LISA), DPS: Ann Hornschemeier Cardiff (Athena, NuSTAR)
- Established Standing Review Board
  - Chair/Deputy: Bill Craig / John Zeimer
  - First NASA milestone review (SRR/SDR) successful Jan ’25
- Clearing NASA programmatic milestones
  - “Acquisition Strategy Meeting” with NASA/HQ on Apr. 17th
  - KDP-B scheduled for July
- Worked with ESA to consolidate hardware requirements and schedule
- Substantial progress in technology development

Hardware Progress

EDU Telescope (NASA/GSFC/L3 Harris Corp)



TRL-5 Laser Demonstrator (GSFC/ Avo photonics / Fibertek)



TRL-5 Charge Management Device (UF)

What is the LISA Science Team?

Dr. Joey Shapiro Key

U. Washington Bothell

LISA Science Team Member

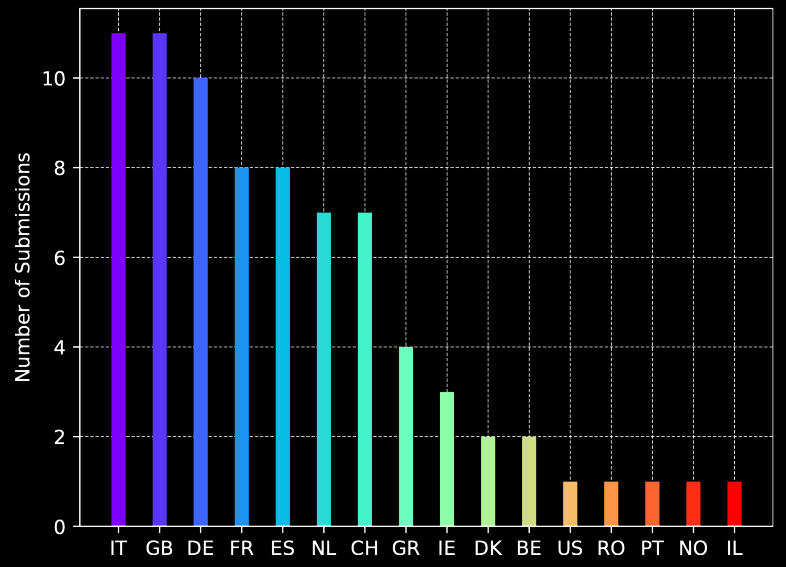
LISA Science Team Charge

LISA Science Management Plan (SMP) LST charge:

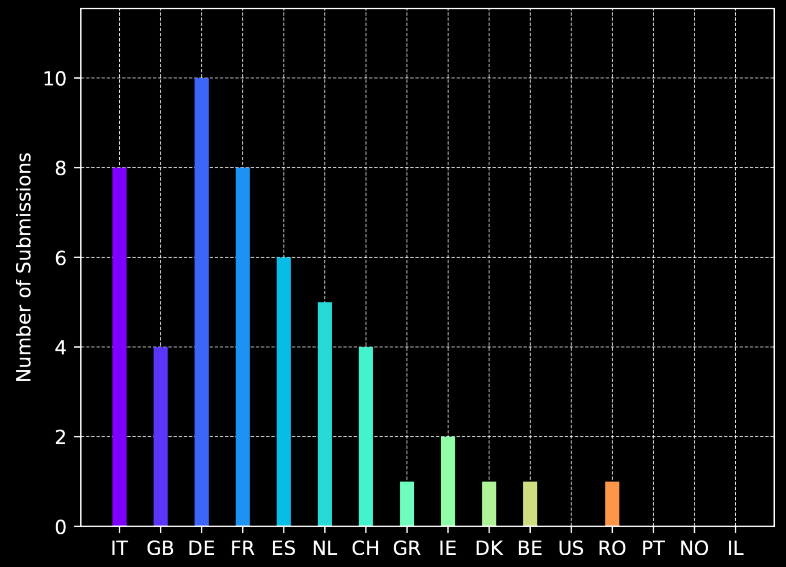
- Maximising the scientific return of LISA
- Optimising:
  - The scientific performance of the instrument and spacecraft;
  - The gravitational wave calibration strategy (formulating and maintaining also);
  - Access to the data via the mission archive(s);
  - Analysis and utilisation of LISA data;
- Overseeing the generation of the Level-3 source catalogue from Level-2 data products;
- Authorising the release of scientific data products to the community;
- Establishing Working Groups;
- Establishing and managing the Science Topical Panels (STPs) of the Early Release Science Time;
- Promoting public awareness

LISA Science Team Selection: ESA

Letters of Intent (78)



Applications (51)



CO-CHAIRS: 2 (ESA +US)

11 European Members

6 US Members

2 Interdisciplinary

1 Consortium Rep.

LISA Science Team Members

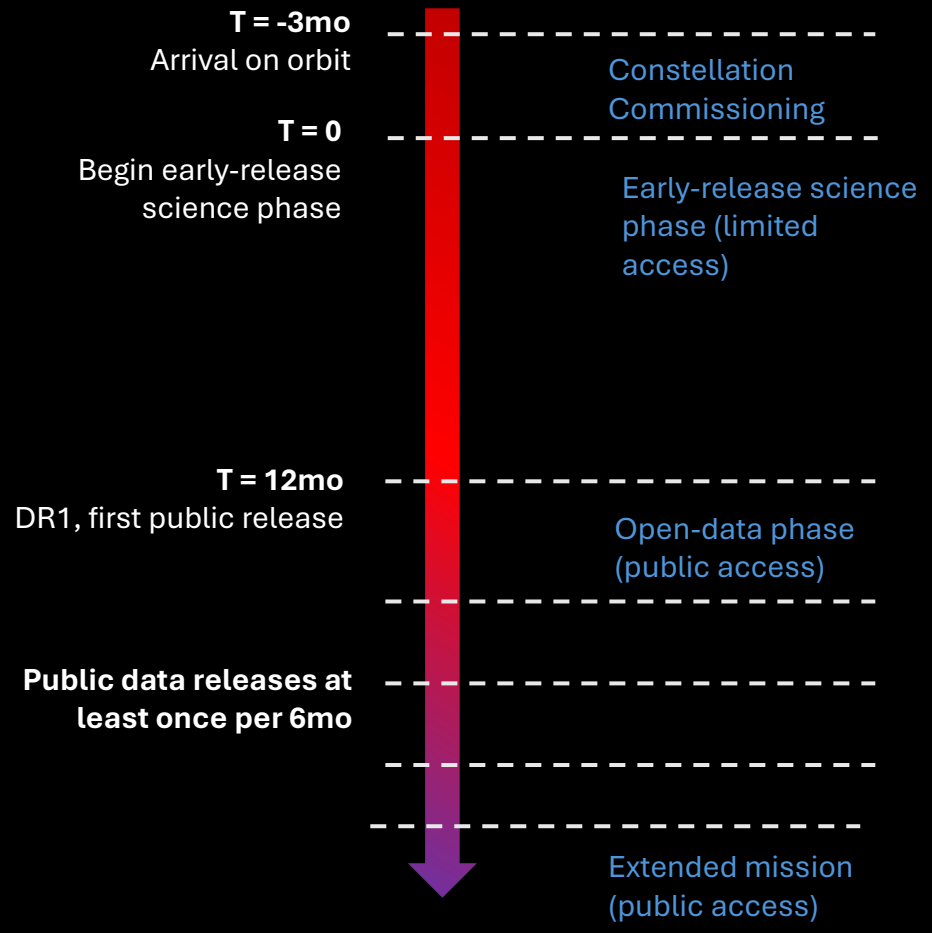
LISA Science Team Meetings

LISA Science Team @ NASA GSFC for Face to Face Meeting, April 8-9, 2025

ESA and NASA Project Scientists and Deputy Project Scientists
(Left to right: Ann HC, Nora L, Oliver J, Ira T.)

Summary of Science Data Policy

- Balance multiple factors
  - Maximizing science opportunity
  - Ensuring validity of results
  - Recognizing past contributions from science community
  - Motivating future contributions from science community
- Highlights of agreement
  - Initial 12mo Early Release Science Time (ERST) with limited data access
  - Science Topical Panels, selected in advance, will have access to LISA data and project experts during ERST
  - First public data release at 12mo, likely accompanied by STP publications
  - Remaining 3.5 years of nominal mission in public data mode with releases at 6mo minimum intervals
  - Releases will contain catalogs plus all lower-level data and tools
- Developing details a key task for ESA-NASA LISA Science Team
  - Selection process for topics and members of Science Topical Panels
  - Details of release contents & process



DATA POLICY

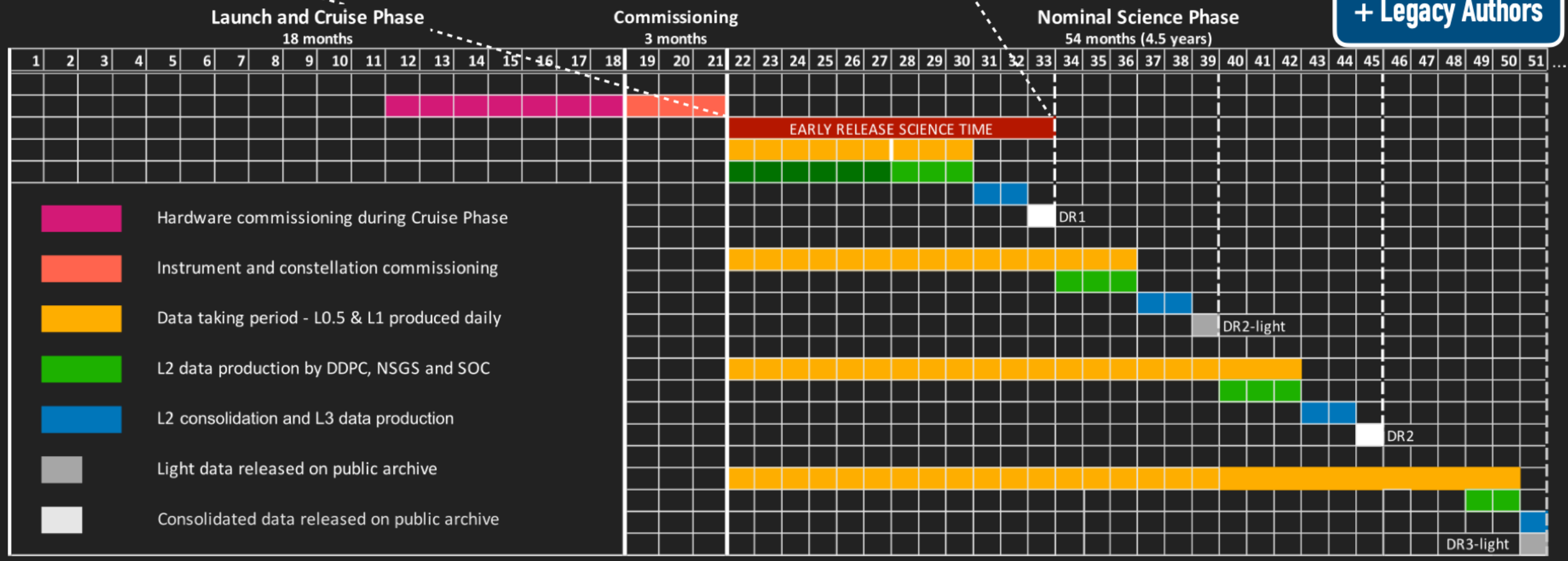
Early Release Science Time (ERST)

- Duration: 12 month
- Data taking: 6 month —> detect Verification Binaries
- Validate instrument performance, pipelines, science data products

Science Topical Panels (STP)

- Selected by LISA Science Team and Whitepapers
- Focus on specific science questions
- Early access to the data
- Publish science interpretation Papers

+ Legacy Authors



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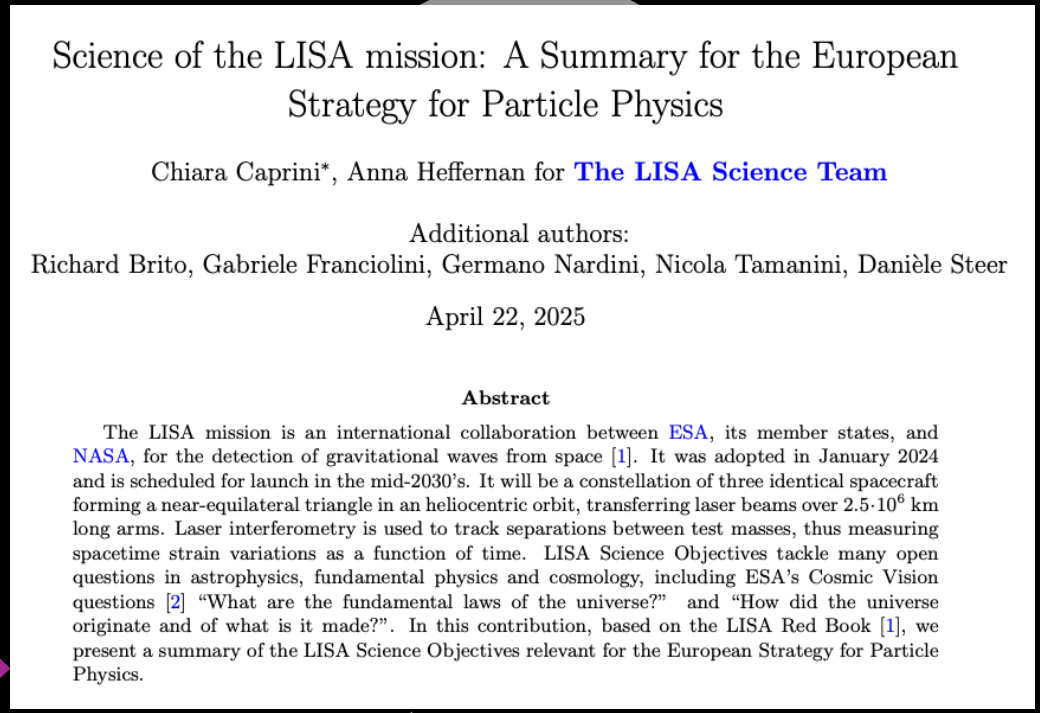
LST COMPLETED TASKS

LISA SCIENCE TEAM 2024-2027

- Team selected by ESA & NASA
- Call and selection of new LST members
- Priority Working Groups formed:
  - Communications
  - LISA Author List
  - L3 catalogue
  - Figures of Merit
  - Science Topical Panels
- LISA summary report for European Strategy for Particle Physics



Science of the LISA mission: A Summary for the European Strategy for Particle Physics

Chiara Caprini*, Anna Heffernan for **The LISA Science Team**

Additional authors:
Richard Brito, Gabriele Franciolini, Germano Nardini, Nicola Tamanini, Danièle Steer

April 22, 2025

Abstract

The LISA mission is an international collaboration between ESA, its member states, and NASA, for the detection of gravitational waves from space [1]. It was adopted in January 2024 and is scheduled for launch in the mid-2030's. It will be a constellation of three identical spacecraft forming a near-equilateral triangle in an heliocentric orbit, transferring laser beams over $2.5 \cdot 10^6$ km long arms. Laser interferometry is used to track separations between test masses, thus measuring spacetime strain variations as a function of time. LISA Science Objectives tackle many open questions in astrophysics, fundamental physics and cosmology, including ESA's Cosmic Vision questions [2] "What are the fundamental laws of the universe?" and "How did the universe originate and of what is it made?". In this contribution, based on the LISA Red Book [1], we present a summary of the LISA Science Objectives relevant for the European Strategy for Particle Physics.

LISA Consortium & LISA Science Team

LISA CONSORTIUM

- Collaboration of community members
- Working on optimally preparing and harvesting LISA data
- Supporting the LISA mission informally (i.e. without formal agreement with ESA)
- Promoting LISA and LISA science
- Community building

LISA Science Team

- Formal link between ESA / NASA and community
- Responsible for STP formation
- Responsible for keeping legacy author list
- Responsible for data releases and content (in particular catalogues)
- Appointed by ESA/NASA
- LST working groups can involve community

Summary

- LISA is moving forward
  - 50 years since Bender & Weiss discussed space-based GW detector at a NASA meeting!
  - ESA has selected a spacecraft vendor
  - NASA and ESA MS are completing technology development and preparing for flight procurements
- NASA is moving full speed ahead with a LISA project
  - Project structure and personnel in place
  - First milestone review complete, first key decision point in July
- Groundwork laid for robust US science participation
  - Negotiated data policy consistent with open science principles
  - US representation in ESA-NASA LISA Science Team provides "seat at the table"
  - NASA developing science ground segment contribution