

LISA:
Opens the low-frequency
gravitational universe!



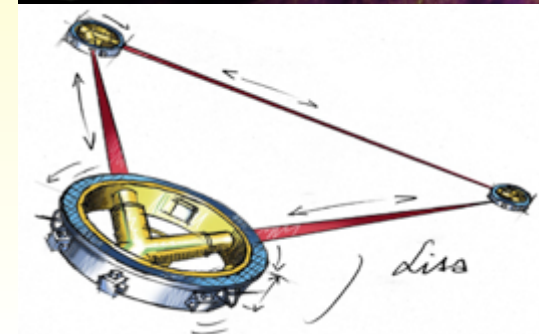
21 Years after the First LISA Symposium at RAL 1996



LISA: A Mature Concept



- M3 proposal for 4 S/C ESA/NASA collaborative mission in 1993
- LISA selected as ESA Cornerstone in 1995
- 3 S/C ESA/NASA LISA appears in 1997
- Joint ESA-NASA Mission Formulation study 2005-2011
- Reformulation 2012-13 as ESA-led eLISA (evolving LISA)
- Now back to 3-arm LISA with NASA



But then in March 2011...



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Now Accepting Submissions!

Published online 22 March 2011 | *Nature* **471**, 421 (2011) | doi:10.1038/471421a

News

Europe makes do without NASA

US budget crisis forces European Space Agency to abandon plans for joint mission.

Stories by keywords

- [European Space Agency](#)
- [L-Class missions](#)
- [LISA](#)
- [IXO](#)
- [ESJM-Laplace](#)

The European Space Agency (ESA) is pushing ahead without NASA support for its next big science mission, as the ongoing US budget crunch and competing priorities impose serious constraints on the US space agency (see [Nature 471, 278; 2011](#)). ESA last week told leaders of three large, or 'L-class', missions that are competing for funding to revise their proposals by leaving out the substantial US contribution that had previously been assumed.

"The decision was made very reluctantly," says David Southwood, director of science and robotic exploration at ESA. "NASA could not meet our timetable to launch."

22 April 2011

- [China hopes research centre can quell food-safety fears](#)
22 April 2011

Related stories

- [US Mars mission takes pole position](#)
08 March 2011
- [ESA on countdown to flagship mission selection](#)

This article elsewhere

[Blogs linking to this article](#)

LISA Redefinition Study



- Redesign for ESA-led mission
- Cost-cap for ESA cost at 850 M€
 - Build on LISA Pathfinder hardware
 - Shorter arms, smaller telescopes, simpler orbits, less mass
 - Use cheaper launcher
 - Cut one arm off !

→ Descoping is an art!



Then came 2015/2016....



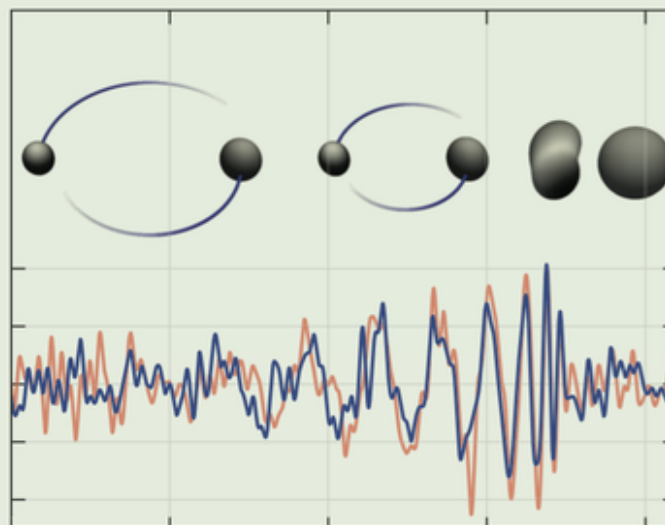
- And two things happened!



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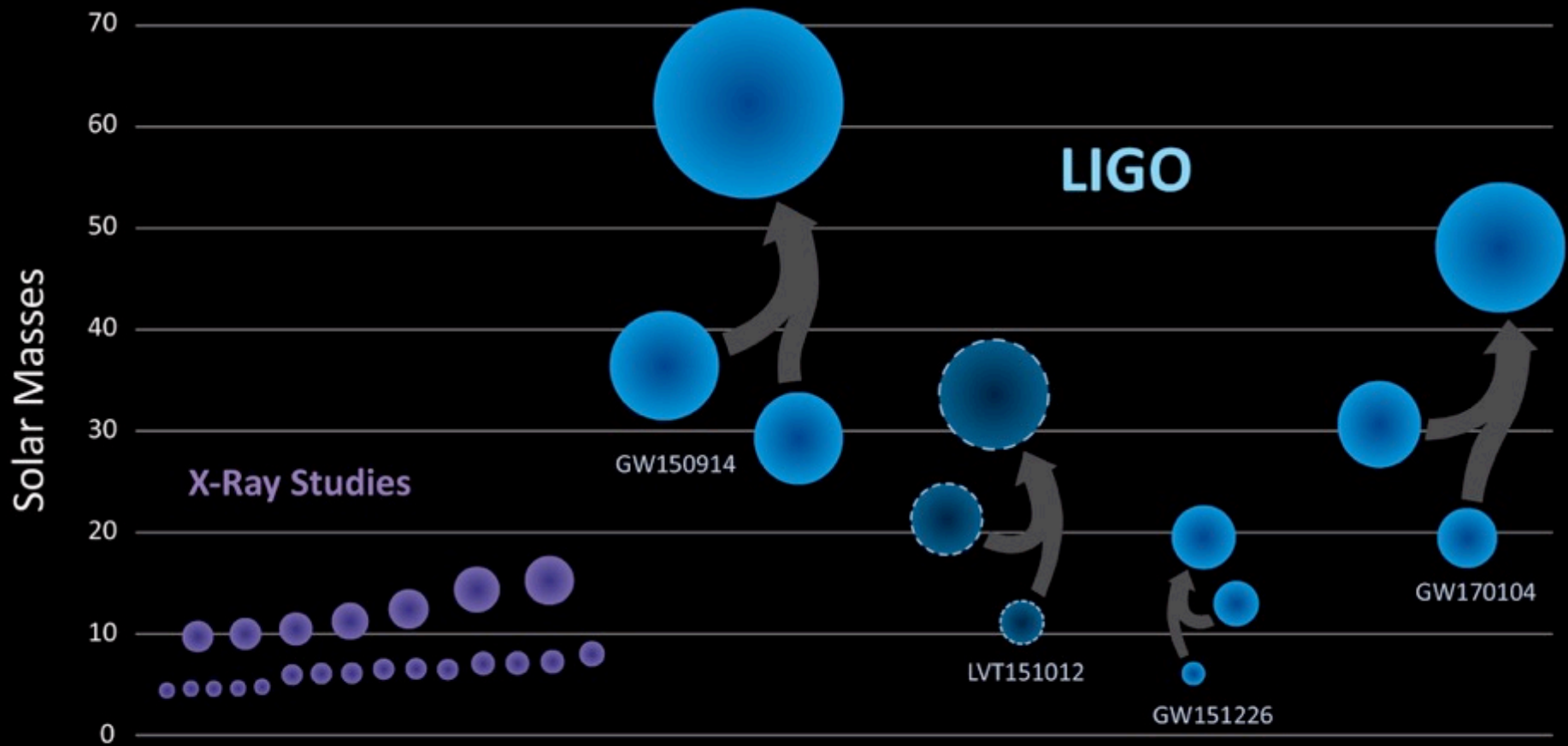


Published by
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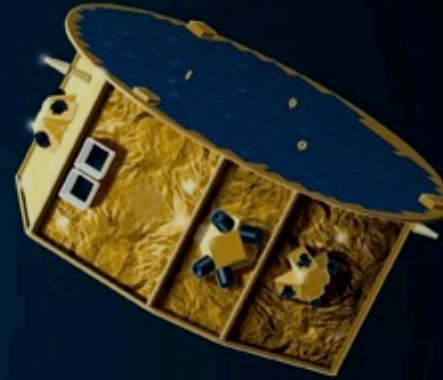
Volume 116, Number 6

Black Holes of Known Mass



Credit: LIGO

LISA Pathfinder

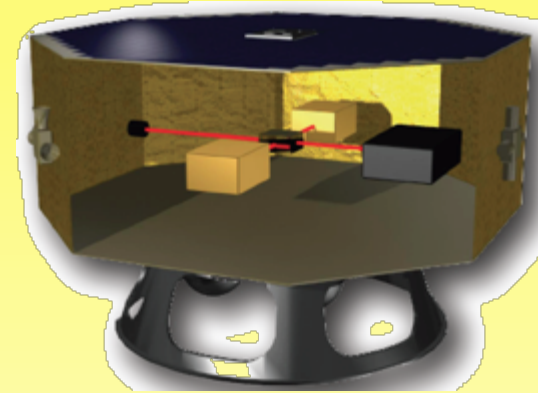


- Testing LISA technology in space!

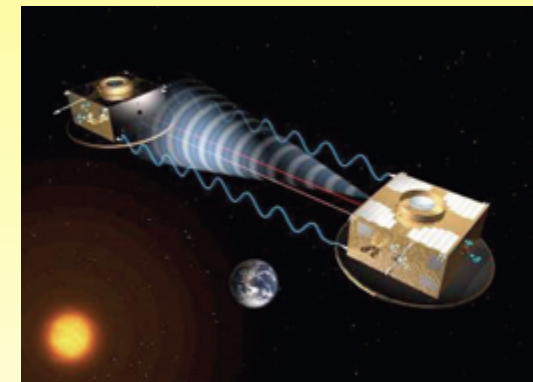
First Proposed in 1998 as ELITE



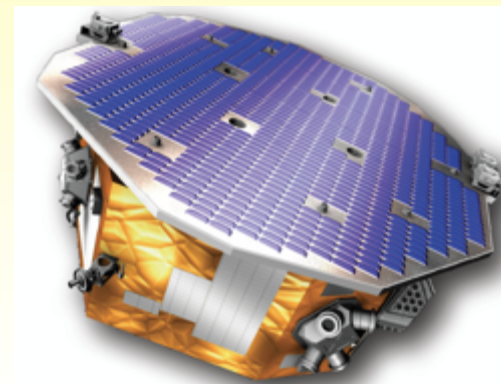
- European LISA Technology Satellite



- Renamed to SMART-2 in 2000
 - Tech demo for LISA and Darwin
 - Launch date 2006



- Descoped to LISA Pathfinder
 - Darwin demo cancelled



17 years later!
September
2015:
Spacecraft is
completed!



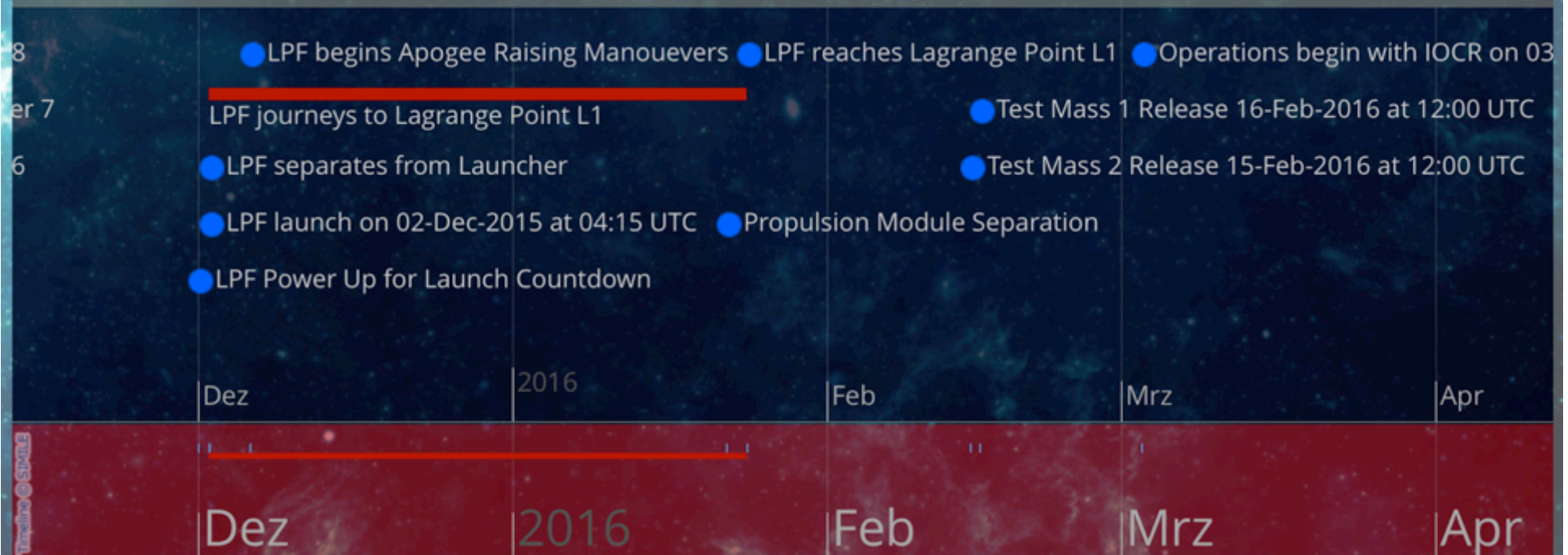
100 Years since GR Publication: Dec. 2, 2015



Countdown to LPF Launch

LPF has launched!

LISA Pathfinder Mission Timeline

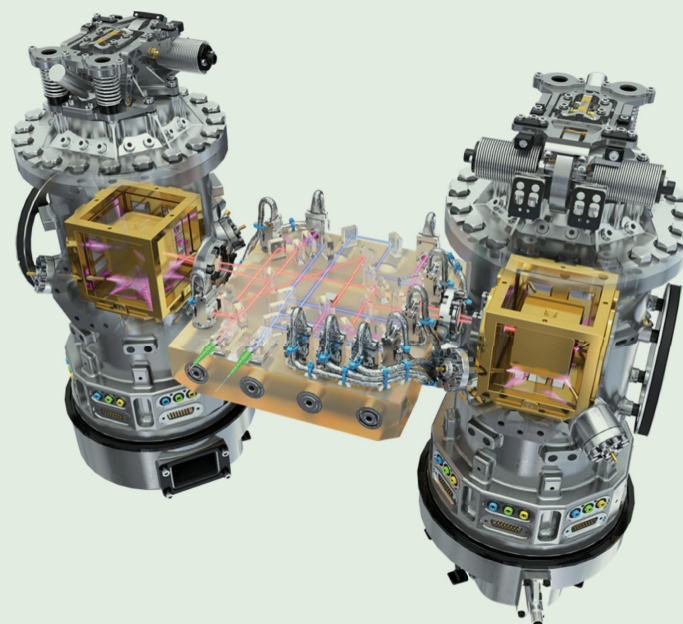




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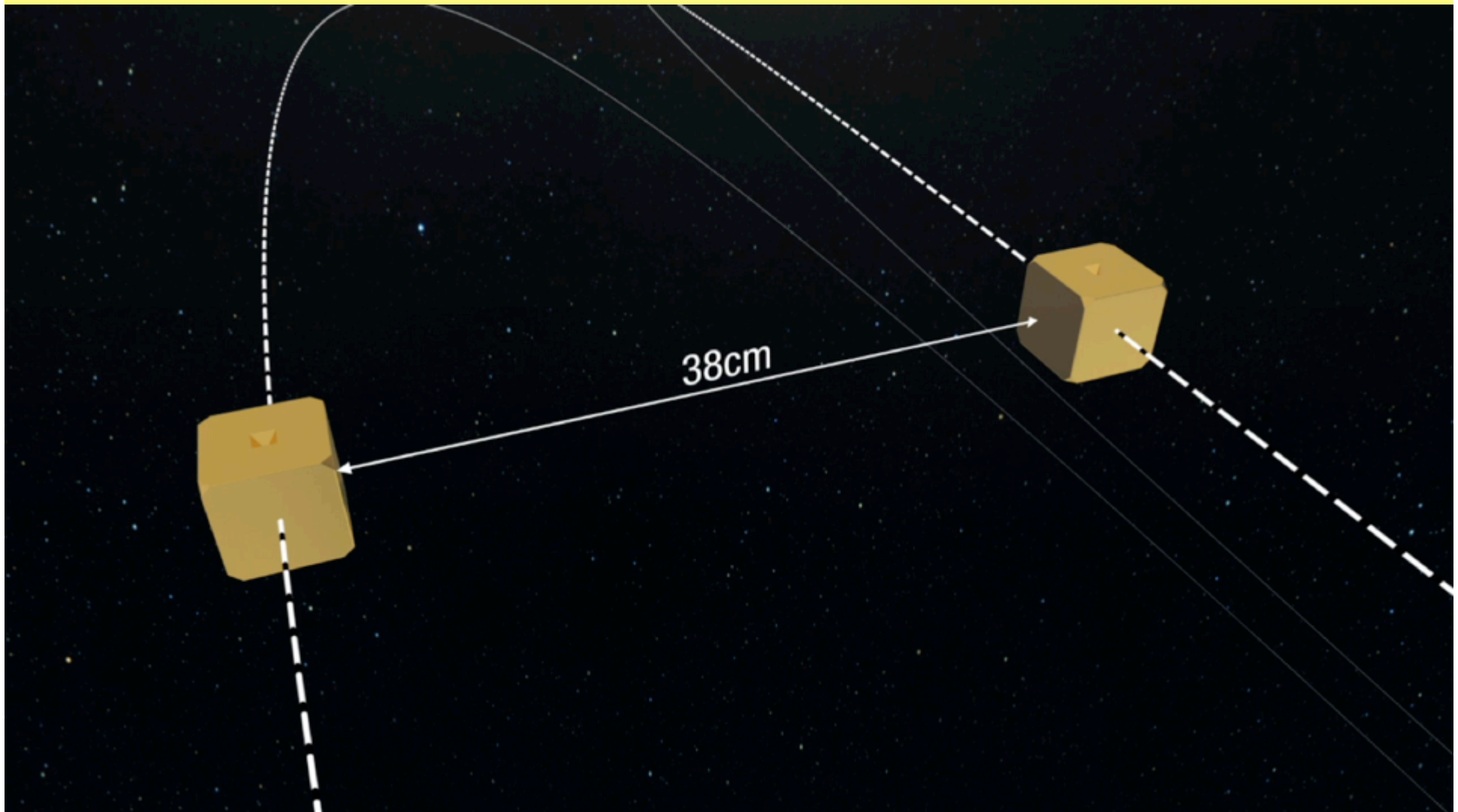


Volume 116, Number 23

The Stillest Place in the Universe!



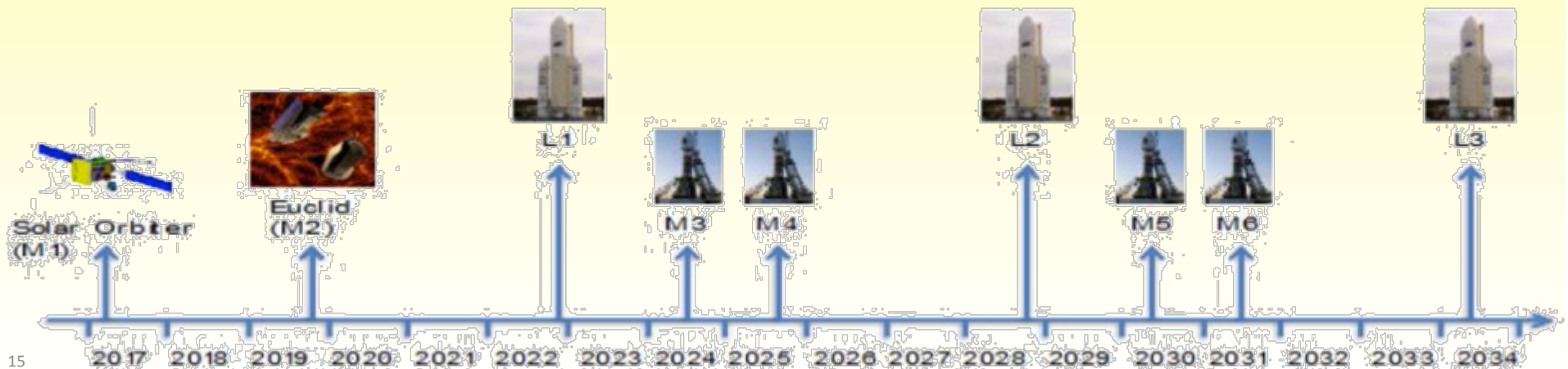
- More sensitive than the weight of a virus!



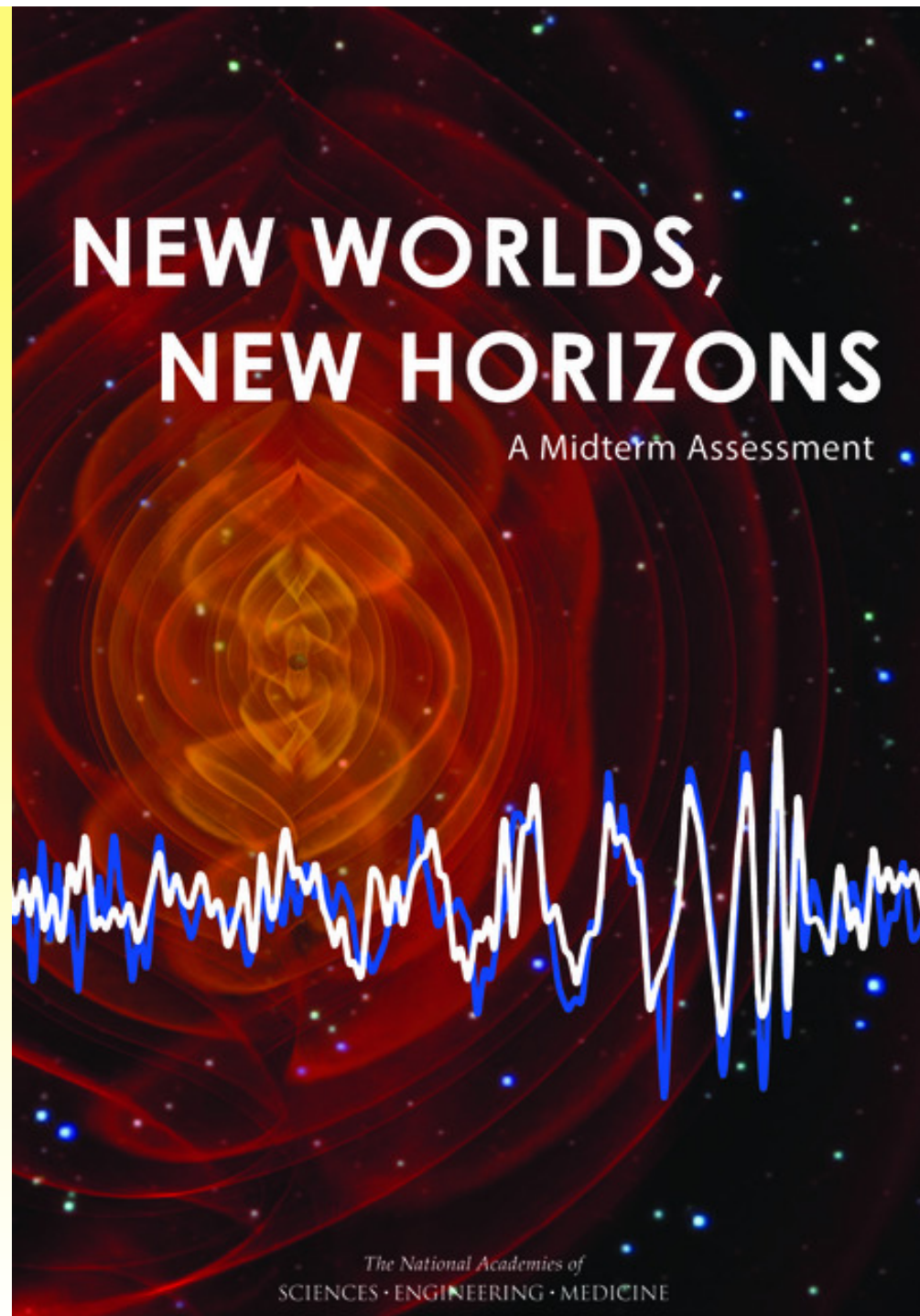
ESA L2 and L3 Missions



- Call for Mission Concepts fall 2016



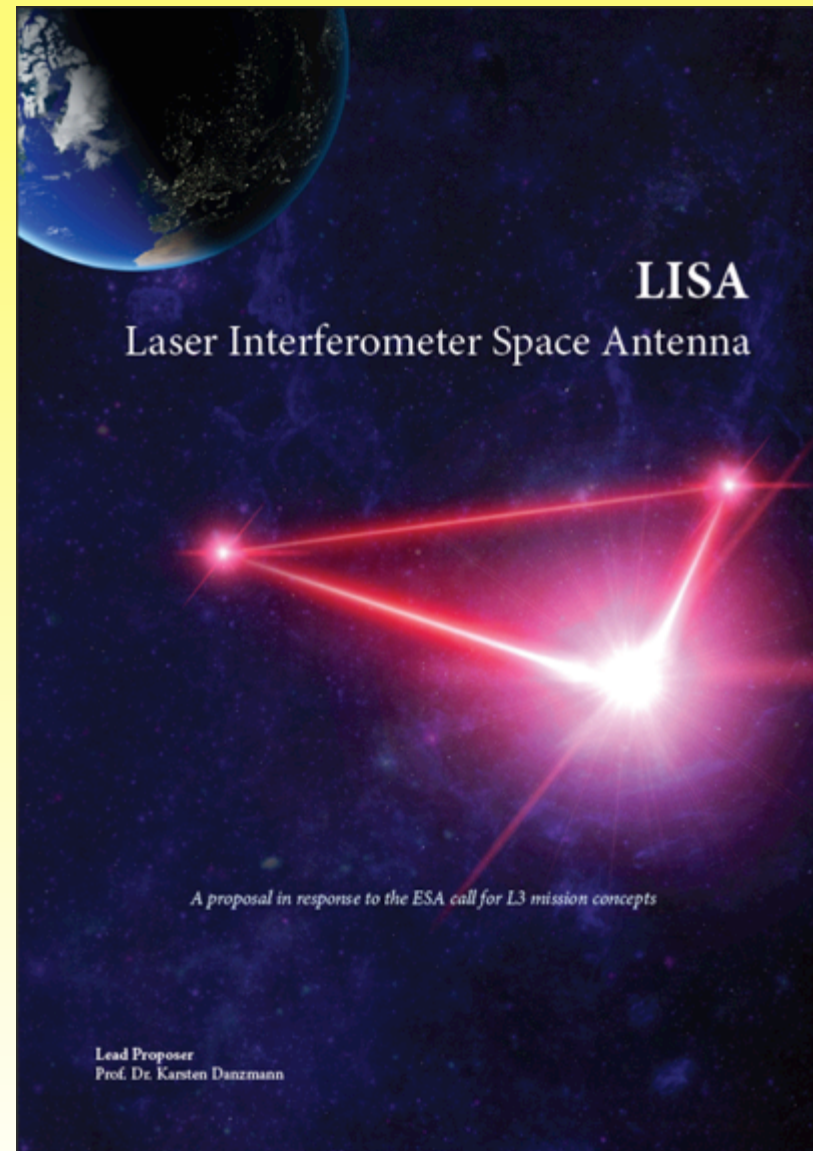
NASA is
back in
LISA!



LISA Mission Concept Document



- Submitted on January 13th, 2017
- The LISA Consortium:
12 EU Member States
plus the US !

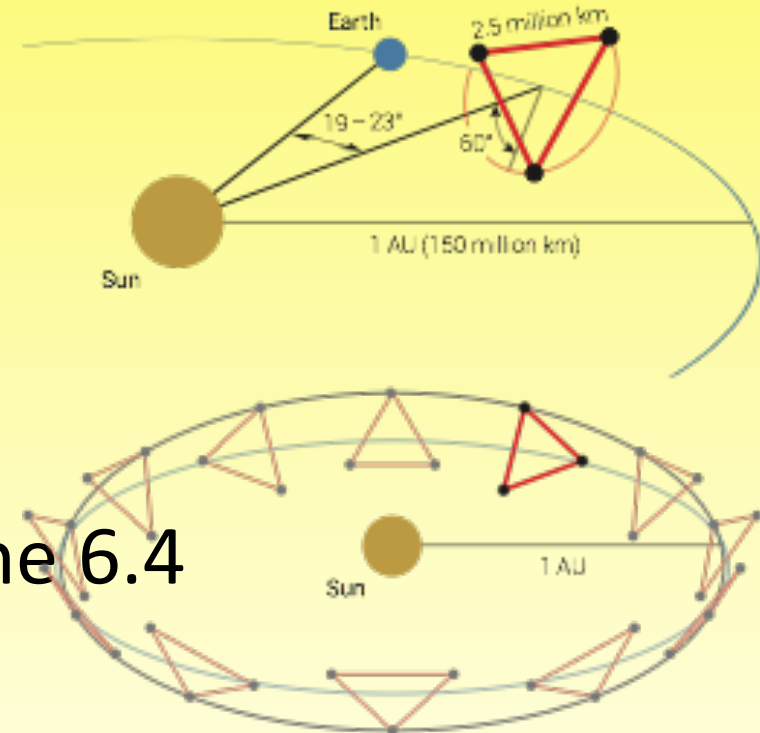


<https://www.lisamission.org/proposal/LISA.pdf>

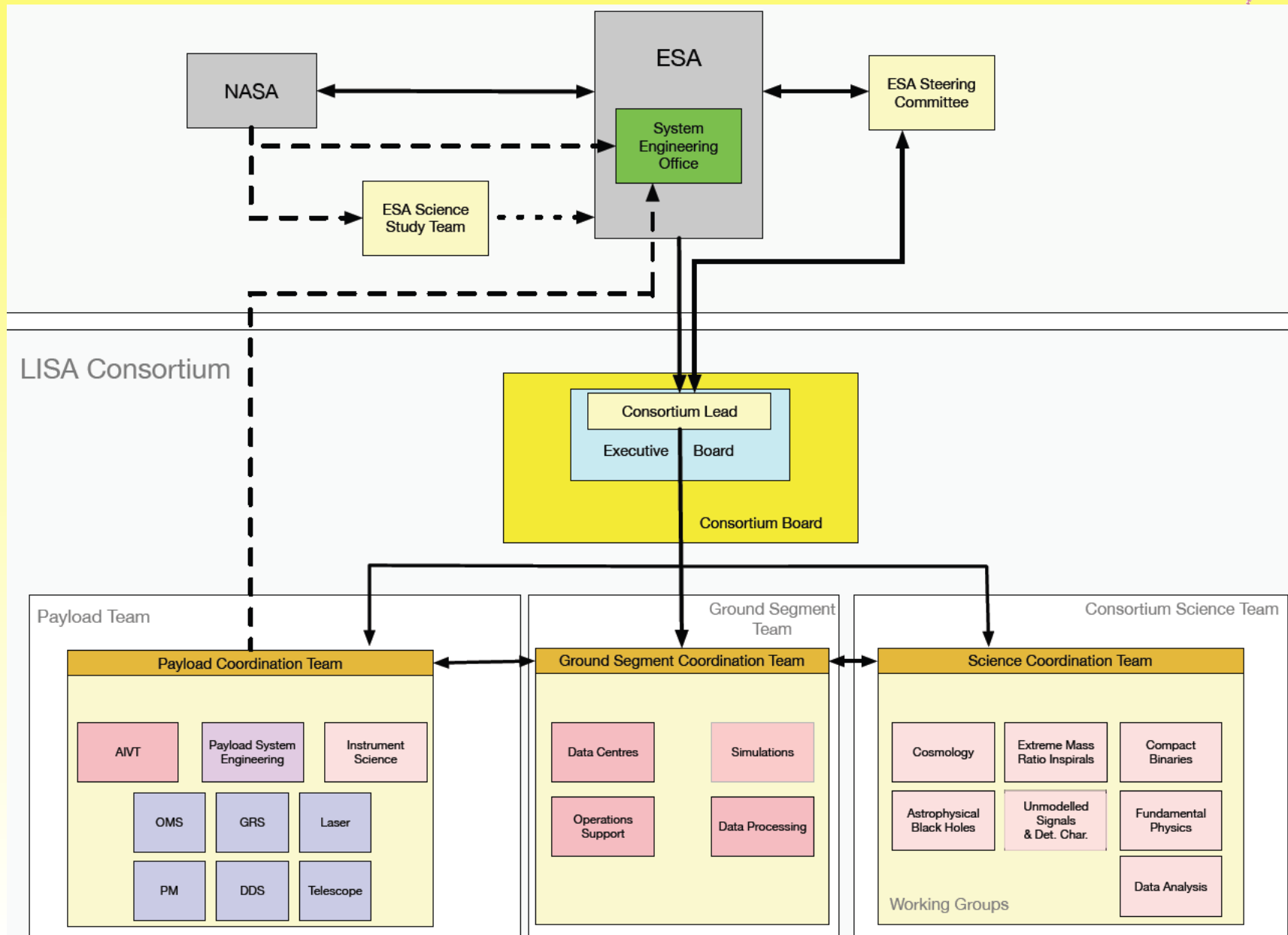
Mission Profile and Orbit



- Three arms of 2.5 Million km
- 2W lasers
- 30 cm telescopes
- Breathing angles ± 1 deg
- Doppler shifts ± 5 MHz
- Launch on dedicated Ariane 6.4
 - Transfer time ~ 400 days
 - Direct escape $V_{\infty} = 260$ m/s
 - Propulsion module and S/C composite



LISA Organigram in Phase A



ESA SPC selected LISA as L3 !



cosmic vision



ESA

SCIENCE & TECHNOLOGY

COSMIC VISION

Missions

- Show All Missions

Cosmic Vision

2015-2025

- Cosmic Vision
- Candidate Missions
- M-class Timeline
- L-class Timeline

Cosmic Vision themes

- The Hot and Energetic Universe
- Planets and Life
- The Solar System
- Fundamental Laws
- The Universe

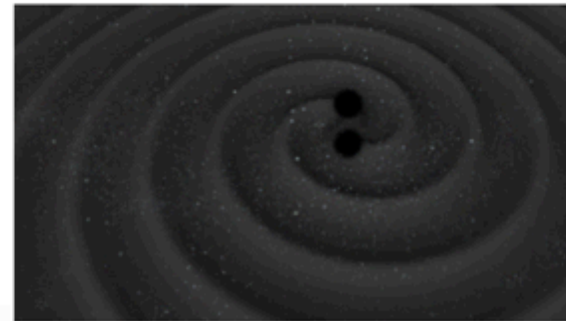
GRAVITATIONAL WAVE MISSION SELECTED, PLANET-HUNTING MISSION MOVES FORWARD

20 June 2017

The LISA trio of satellites to detect gravitational waves from space has been selected as the third large-class mission in ESA's Science programme, while the PLATO exoplanet hunter moves into development.

These important milestones were decided upon during a meeting of ESA's Science Programme Committee today, and ensure the continuation of ESA's [Cosmic Vision](#) plan through the next two decades.

The '[gravitational universe](#)' was identified in 2013 as the theme for the third large-class mission, L3, searching for ripples in the fabric of spacetime created by celestial objects with very strong gravity,



Search here

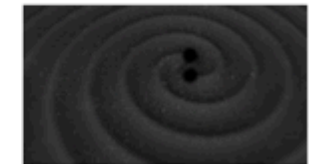


9-Jul-2017 18:39 UT

Shortcut URL

<http://sci.esa.int/jump.cfm?oid=59243>

Images And Videos



- Merging black holes
- Searching for exoplanetary systems

Start of Phase 0: CDF Study



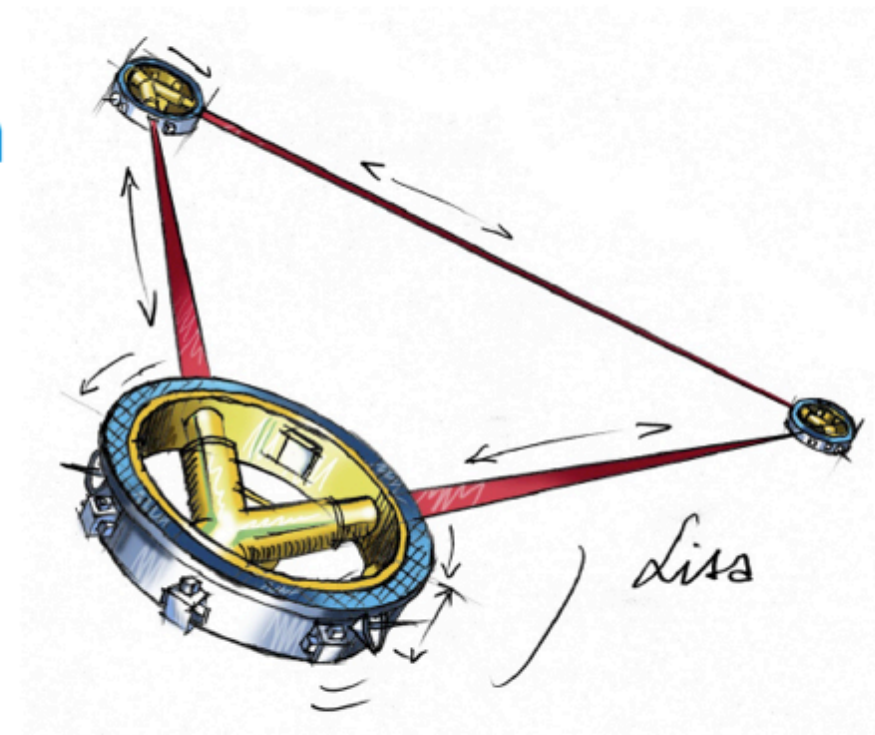
LISA Study Introduction

Systems

Session 1
ESTEC, 08-03-2017

Prepared by the CDF* Team

(*) ESTEC Concurrent Design Facility



Presentation of First Study Phase



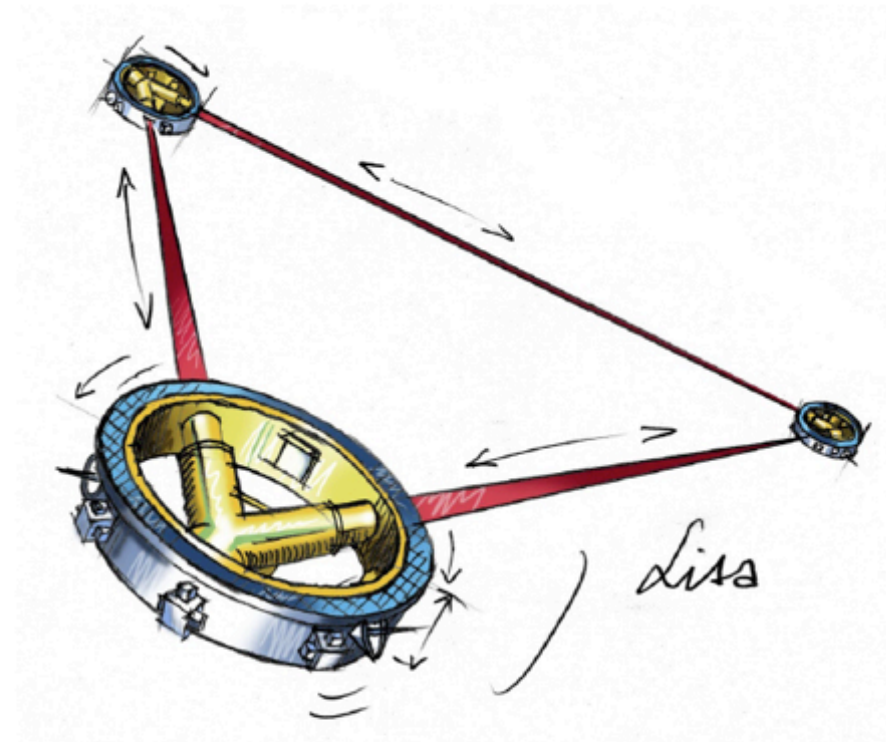
LISA

Welcome

Internal Final Presentation
ESTEC, 05-05-2017

Prepared by the CDF* Team

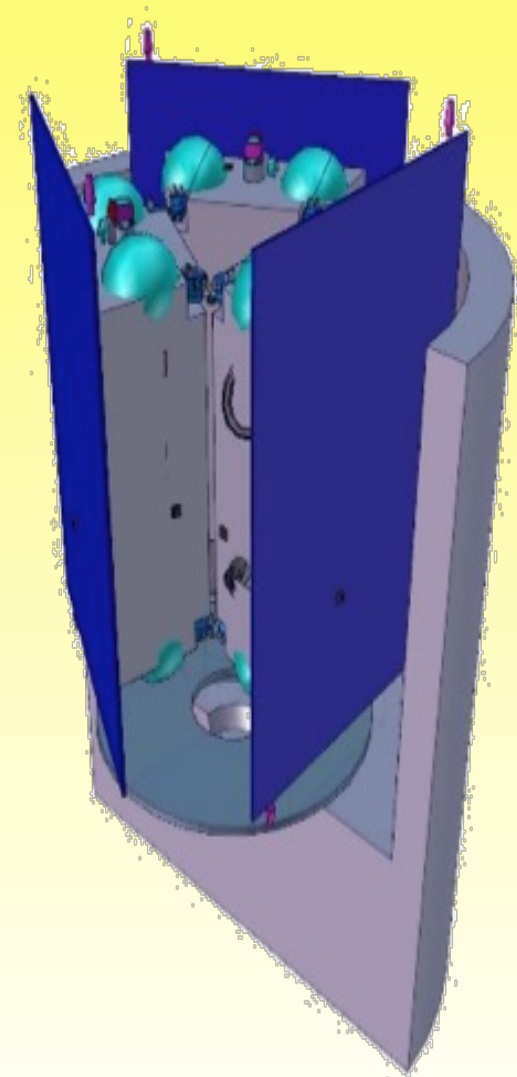
(*) ESTEC Concurrent Design Facility



LISA Phase 0 System Study

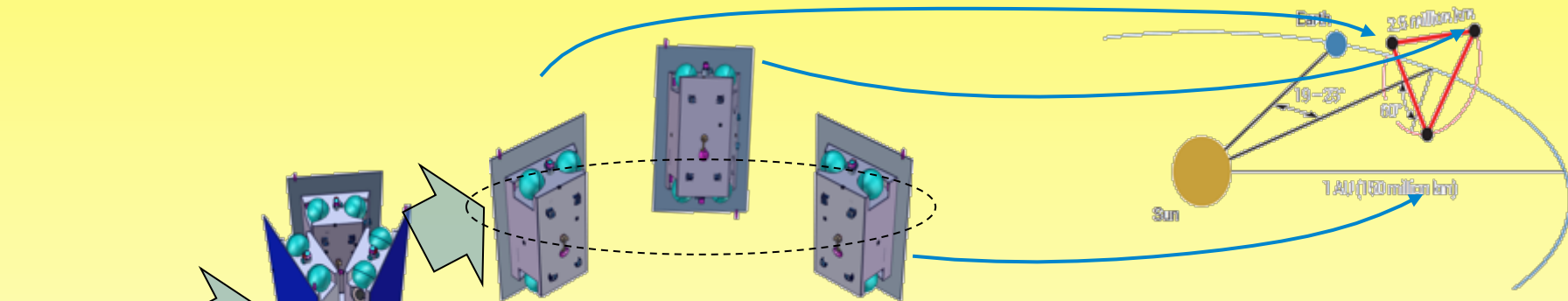


- Feasible technical baseline for LISA
- Dedicated launch with Ariane 6.4
 - Transfer 15 mo + commissioning 9 mo
 - 4 yrs of science operations, extended mission to 10 yrs
- Electric propulsion for orbit transfer, cold gas for micropropulsion
- Payload derived from previous studies, some open trade-offs
- S/C mass 1860 kg, incl. 480 kg P/L, no jettisonable propulsion module
- Power 2.5 kW
- Healthy mass margins (> 1000 kg growth potential)



The Coffin!

Launch and transfer

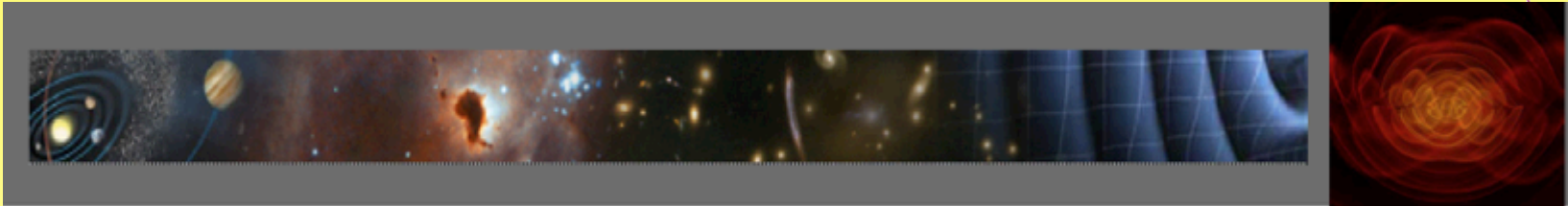


Launch in stacked configuration
Direct injection into escape trajectory

Separation of the stack right after launch

Separate trajectory for each S/C to final orbit

Payload Phase 0 is Running



L3/LISA Phase 0 Planning #1

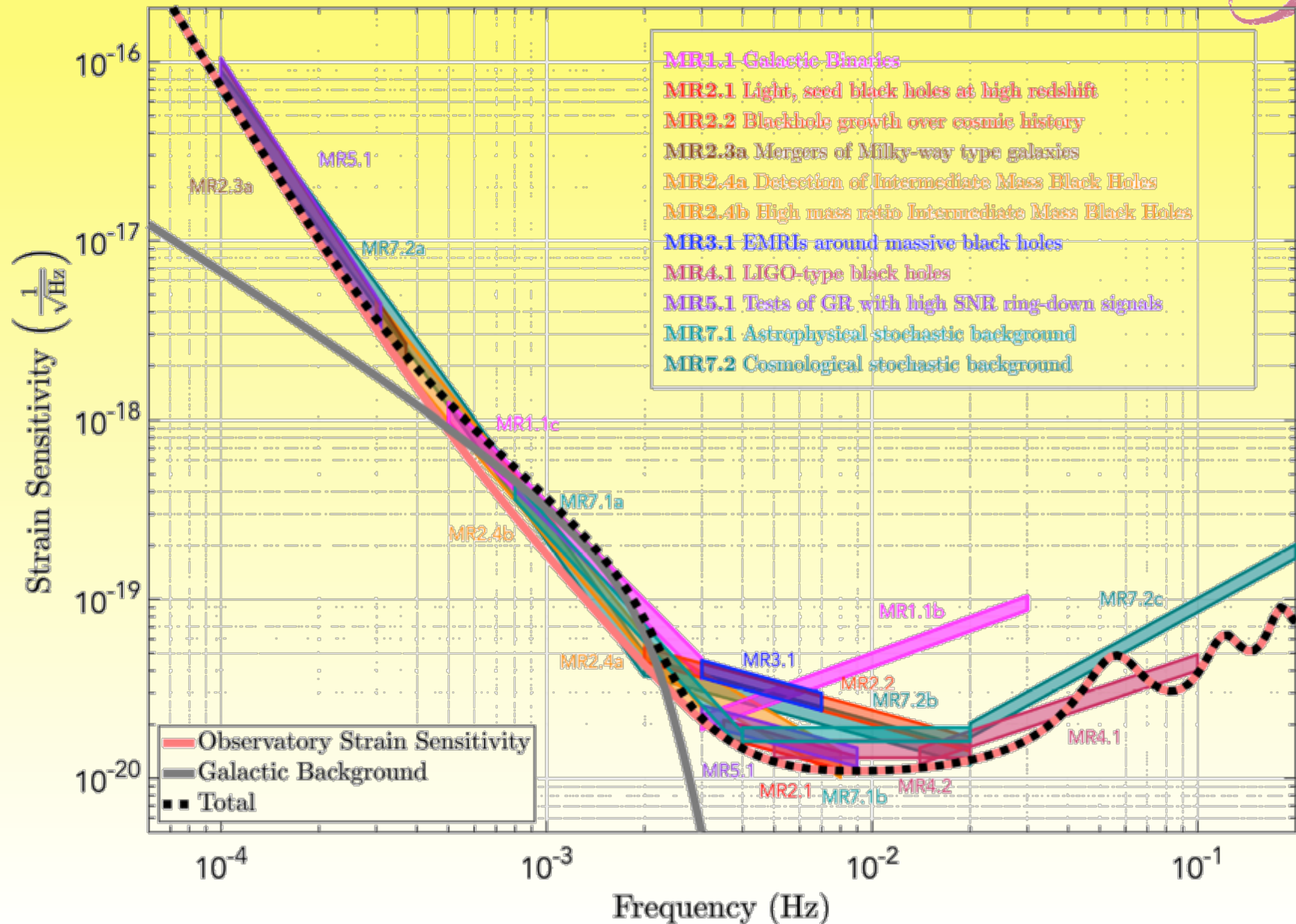
ESOC

24 May 2017

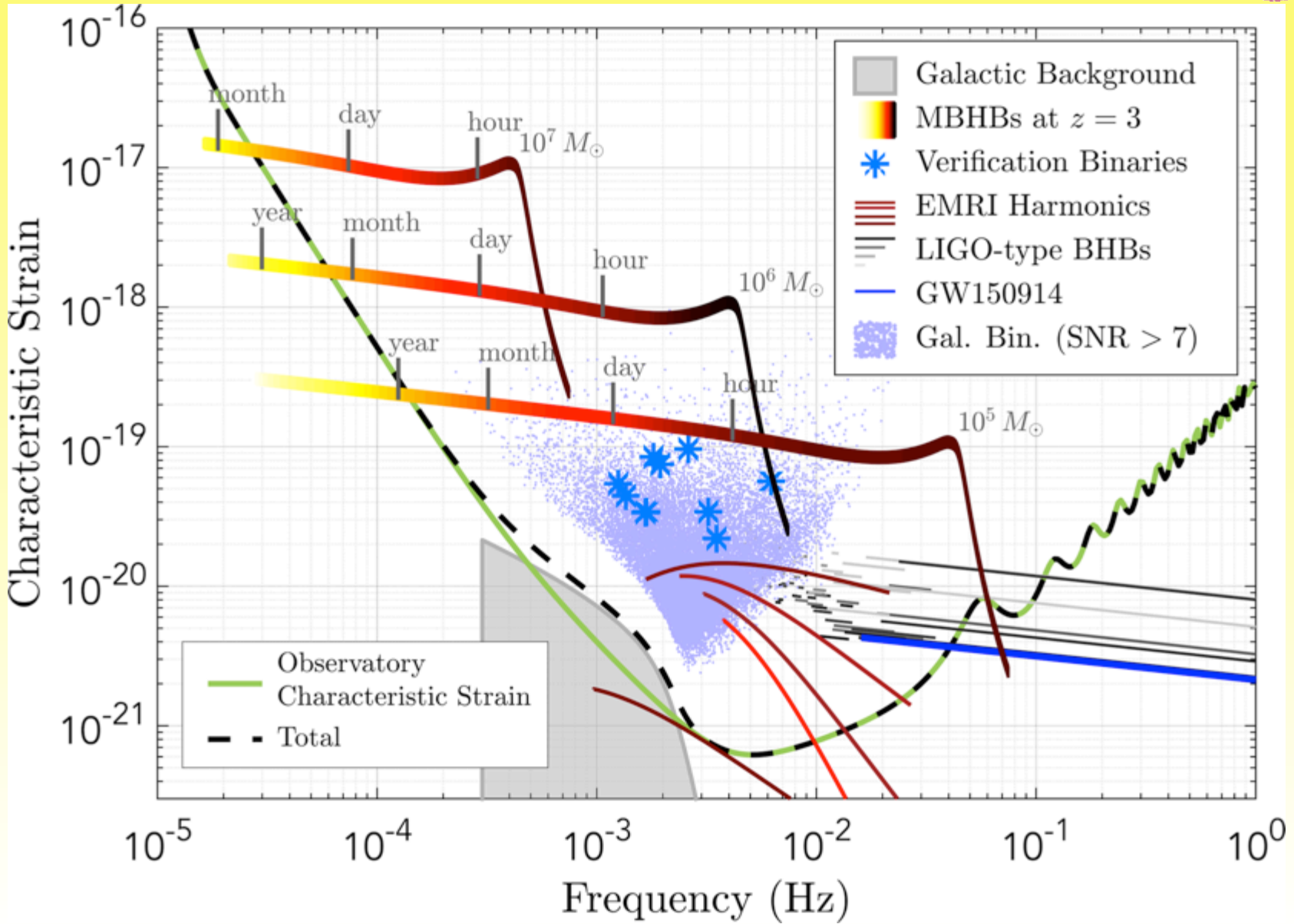
ESA Study Team

ESA-L3-EST-PL-MIN-001

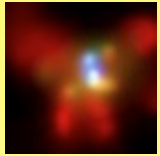
LISA Requirements



LISA Sources

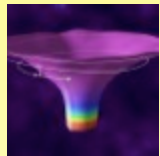


LISA for Astrophysics, Cosmology, and Fundamental Physics



Massive Black Holes (10^4 to $10^8 M_{\odot}$)

- When did the first Black Holes appear in pre-galactic halos and what is their mass and spin?
- How did Black Holes form, assemble and evolve from cosmic dawn to present time, due to accretion and mergers?
- What role did Black Holes play in re-ionisation, galaxy evolution and structure formation?
- What is the precise luminosity distance to loud standard siren black hole binaries?
- What is the distance – redshift relation and the evolution history of the universe?
- Does the Graviton have mass?



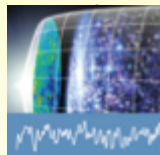
Extreme Mass Ratio Inspirals, EMRIs (1 to $10 M_{\odot}$ into 10^4 to $5 \times 10^6 M_{\odot}$)

- How is the stellar dynamics in dense galactic nuclei?
- How does dynamical relaxation and mass segregation work in dense galactic nuclei?
- What is the occupation fraction of black holes in low-mass galaxies?
- How large are deviations from Kerr Metric, and what new physics causes them?
- Are there horizonless objects like boson stars or gravastars?
- Are alternatives to GR viable, like Chern-Simons or scalar tensor theories or braneworld scenarios?



Ultra-Compact Binaries in Milky Way

- What is the explosion mechanism of type Ia supernovae?
- What is the formation and merger rate of compact binaries?
- What is the endpoint of stellar evolution?



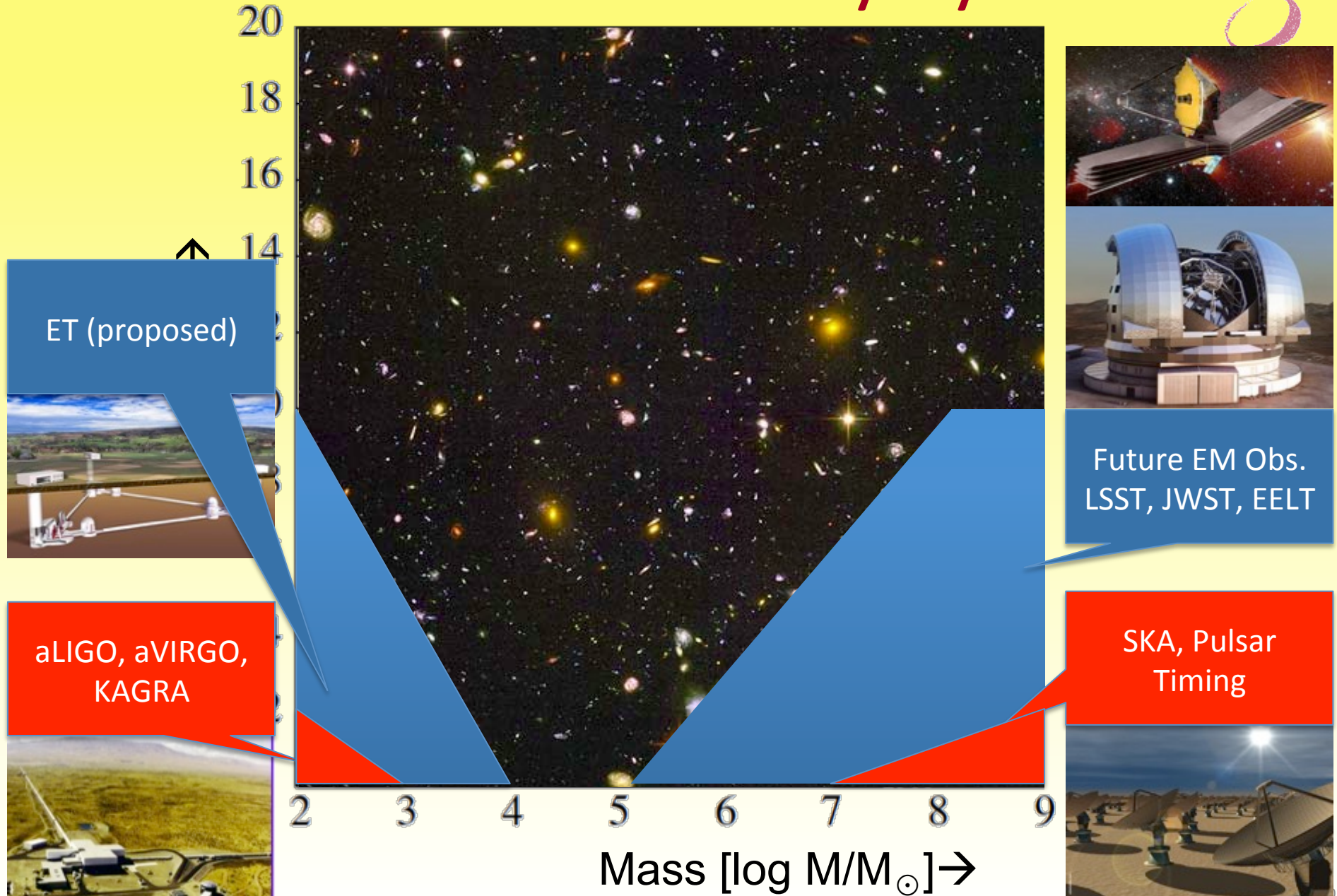
Stochastic Signals

- Directly probe Planck scale epoch at 1 TeV to 1000 TeV before decoupling of microwave background
- Were there phase transitions and of which order?
- Probe Higgs field self coupling and potential, and search for supersymmetry.
- Are there warped sub-millimetre extra-dimensions?
- Can we see braneworld scenarios with reheating temperatures in the TeV range?
- Do topological defects like Cosmic Strings exist?

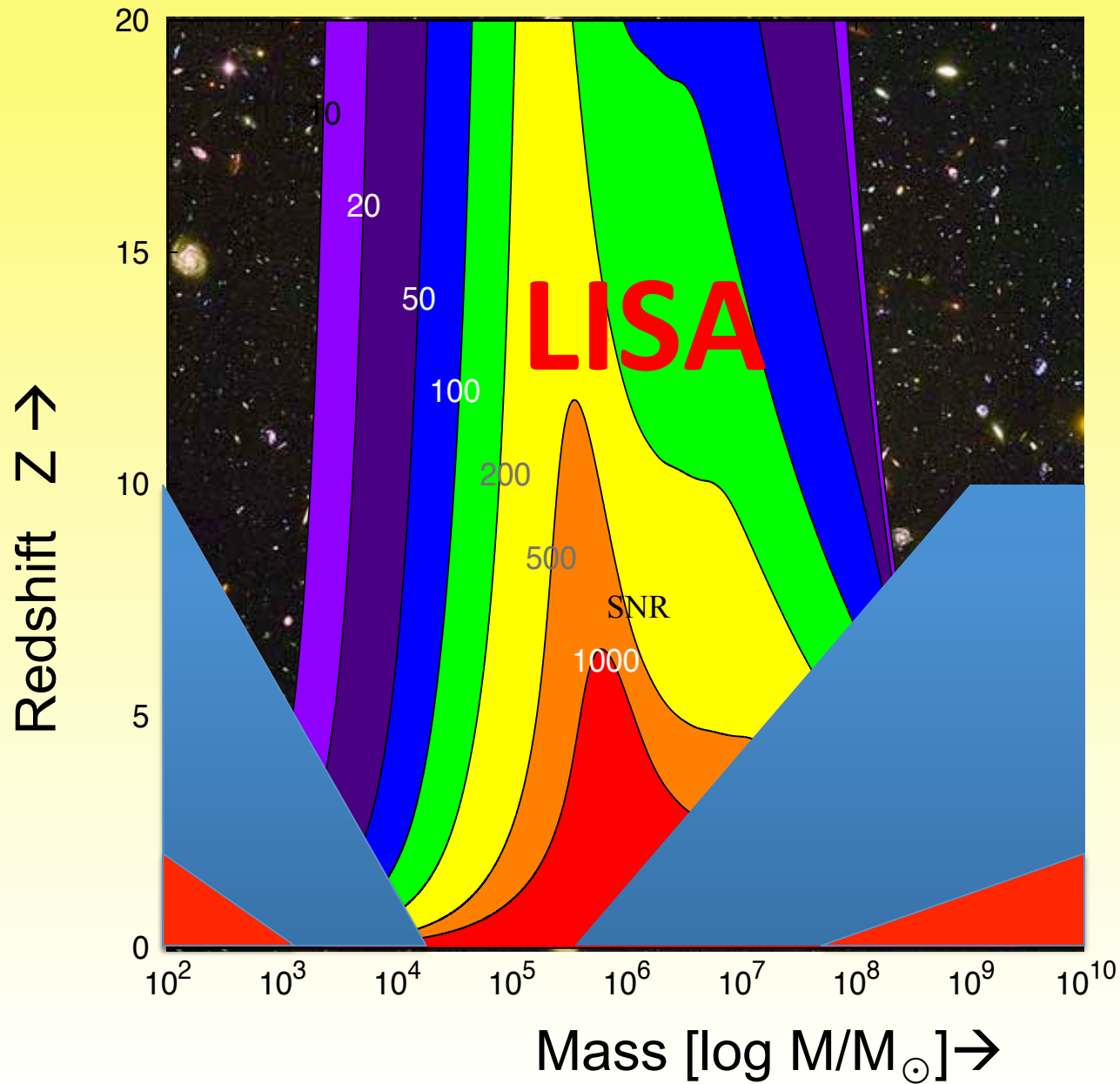
???

The Unknown !

Black Hole Astronomy by 2030



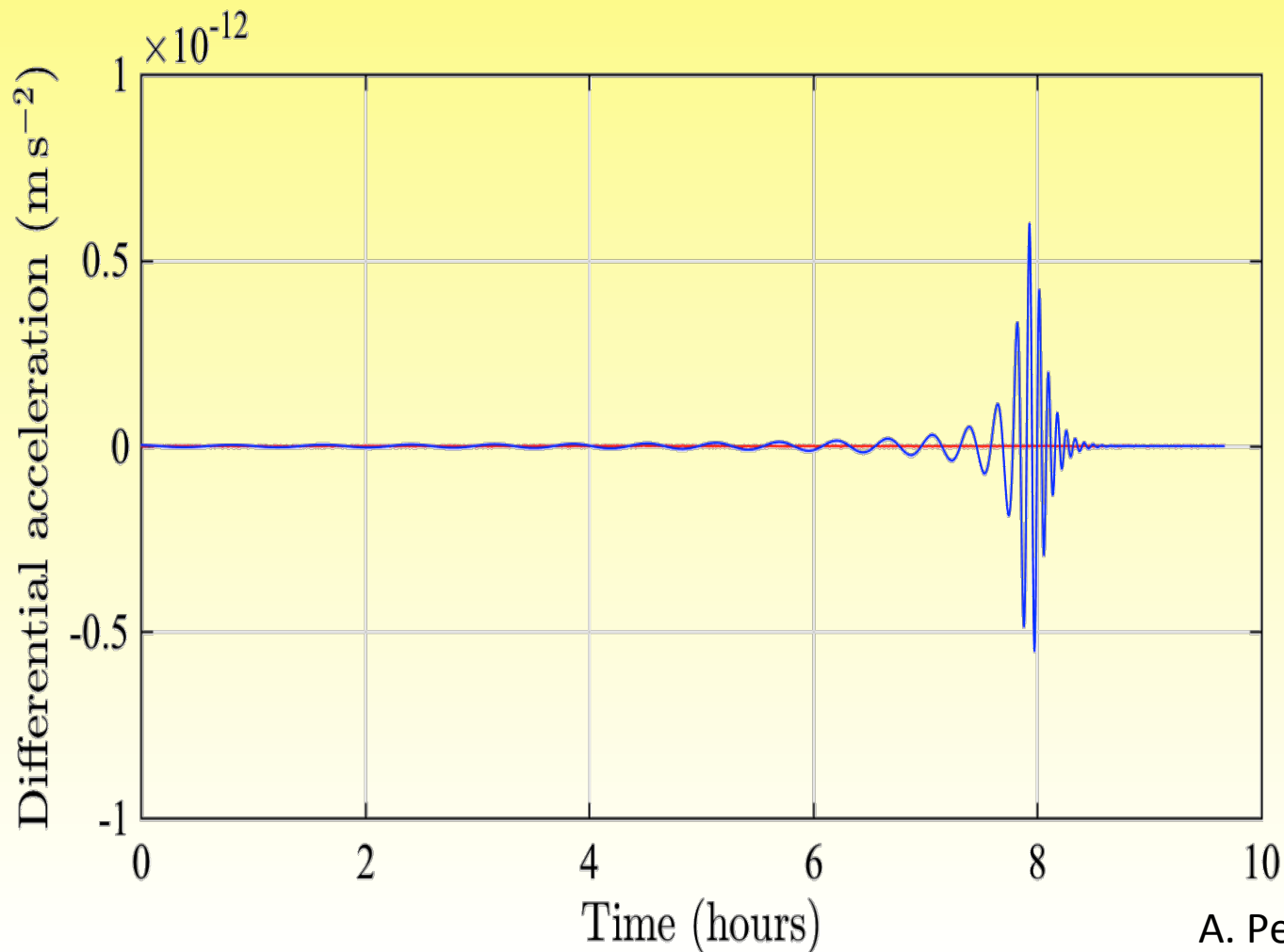
Black Hole Astronomy by 2030



Black Hole Mergers far above Noise



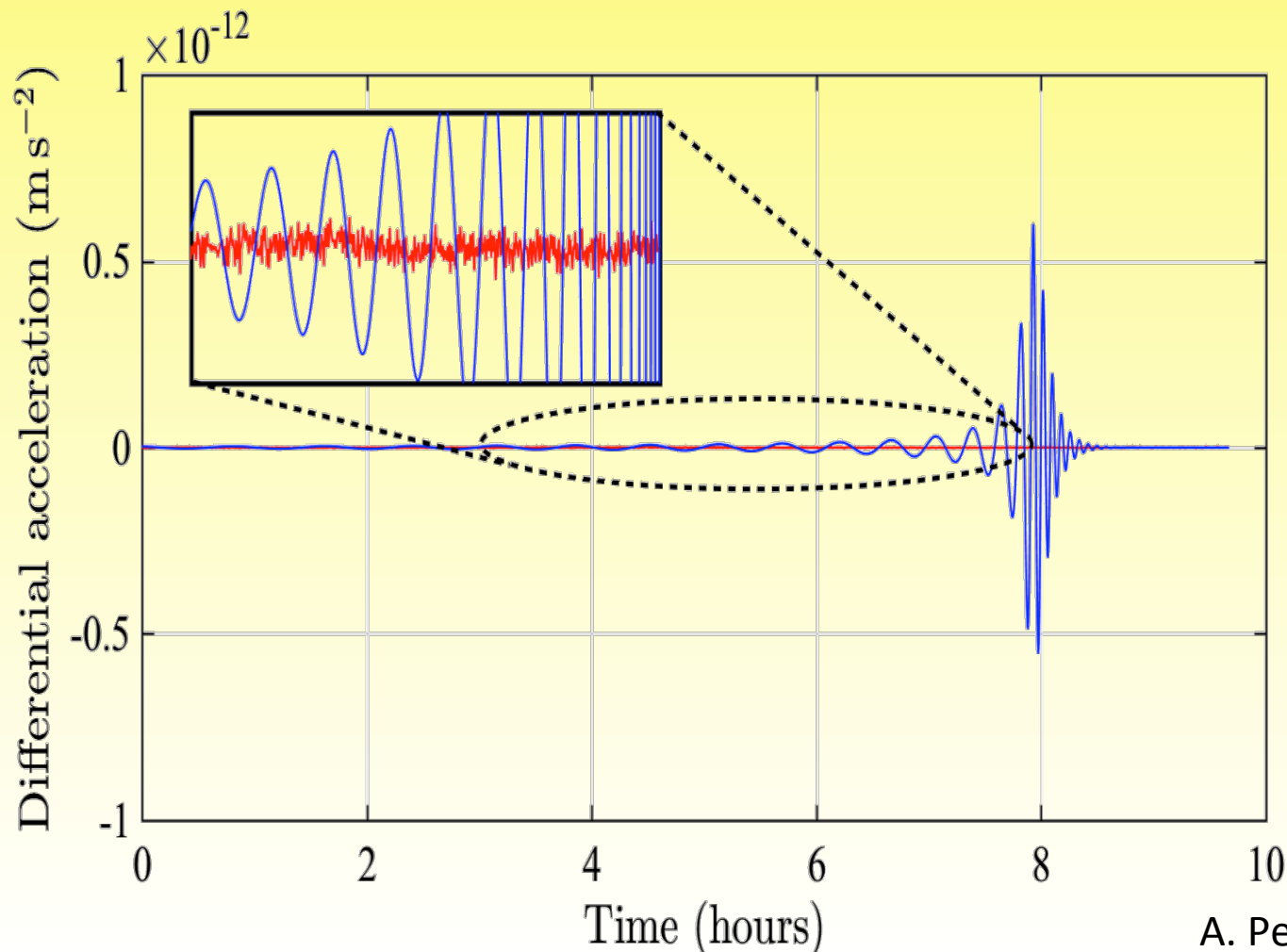
- $10^5 M_{\odot}$ BH binary merger at $z=5$
- In Red: Pathfinder instrumental noise



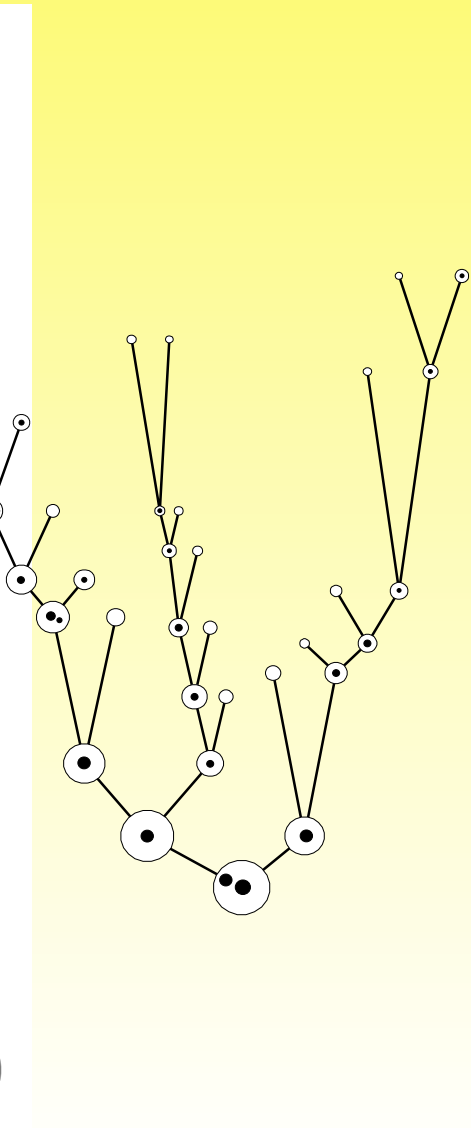
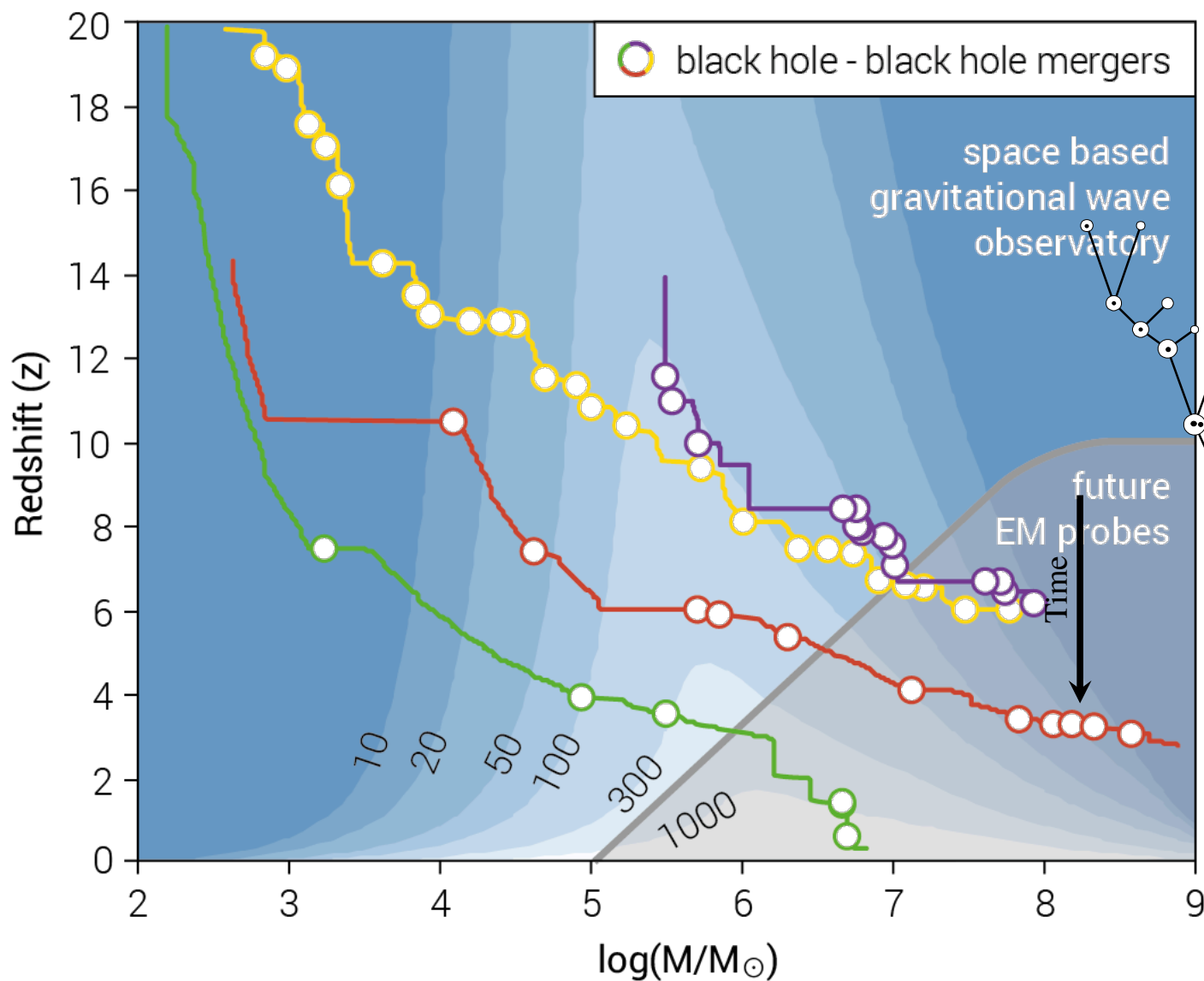
Black Hole Merger far above Noise



- $10^5 M_{\odot}$ BH binary merger at $z=5$
- In Red: Pathfinder instrumental noise



All Binary Black Holes cross LISA band: Trace Galaxy Mergers



Cosmology with Standard Sirens

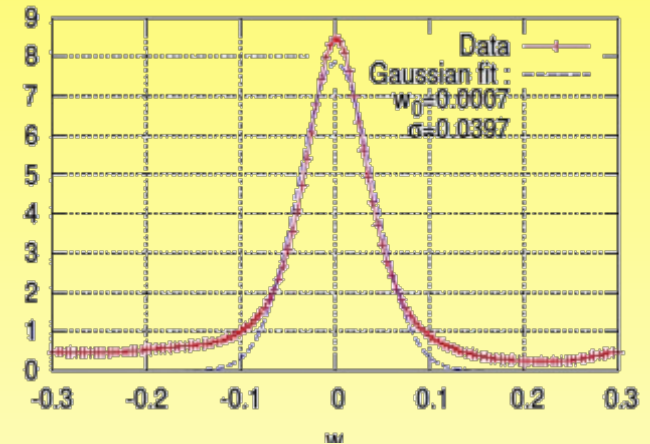


- With luminosity distances, LISA gives accurate and independent measurements of H_0 and w .

- EMRIs, *without* EM counterparts:
- Hubble const. H_0 to $\pm 0.4\% = \pm 0.3 \text{ km s}^{-1} \text{ Mpc}^{-1}$ after 20 EMRI detections: ~ 3 months LISA (MacLeod & Hogan, PRD, 2008; SDSS)
- Compare WMAP: $\pm 1.2 \text{ km s}^{-1} \text{ Mpc}^{-1}$.
- MBH mergers out to $z = 3$, *no* EM counterparts:
- Dark energy equation of state parameter w to $\pm 2\text{-}4\%$ in 3 years (Petiteau et al, ApJ, 2011; Millennium).
- Compare EUCLID: $\pm 2\%$.

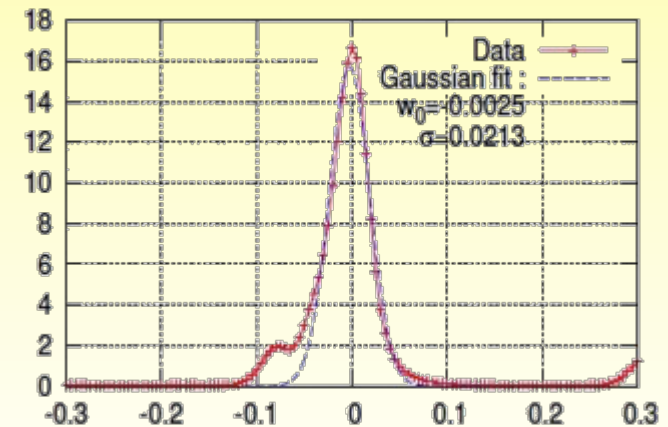
No identifications

(b) without electromagnetic counterpart



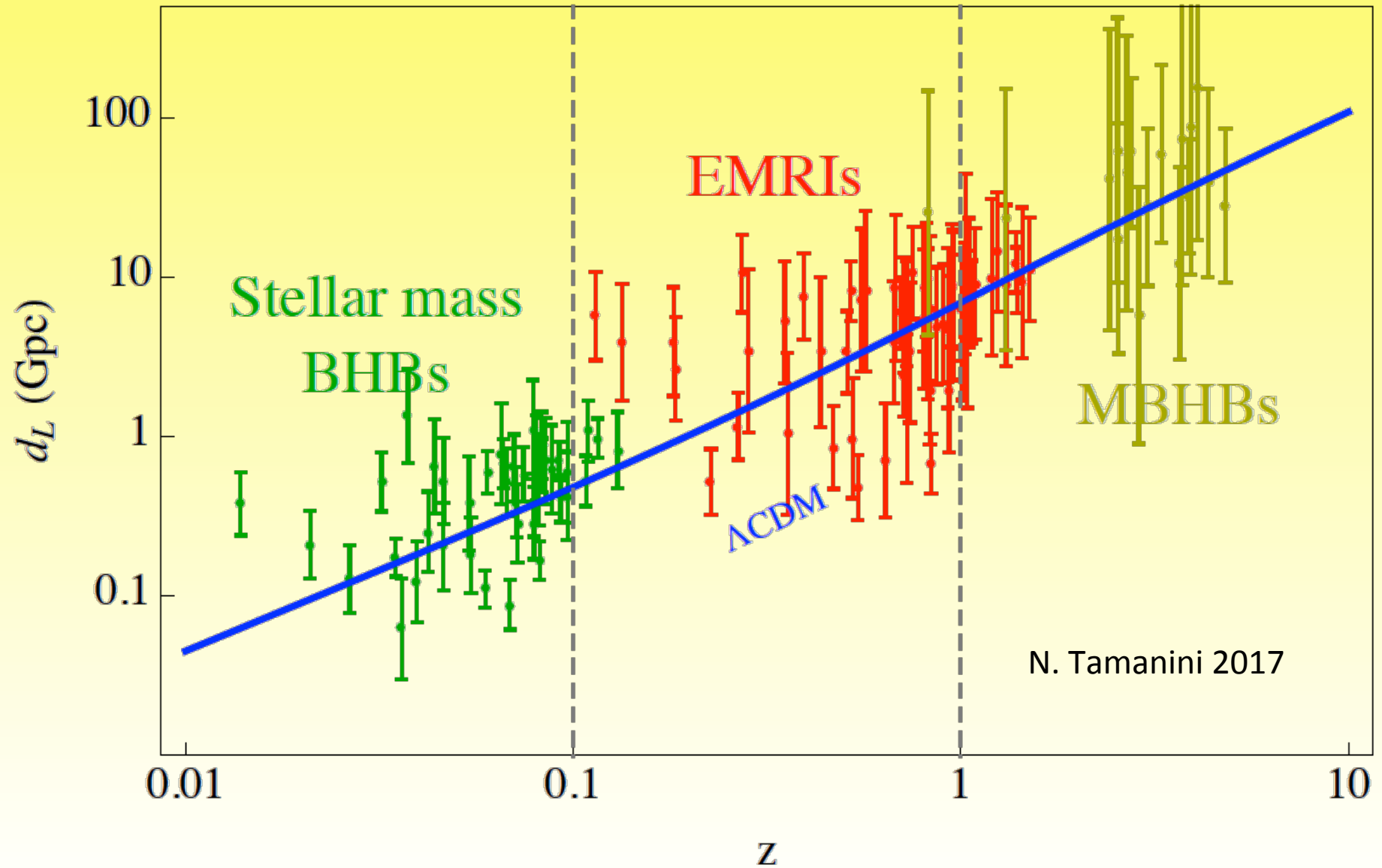
With identifications

(f) improved WL + merger



Dark Energy equation-of-state parameter w

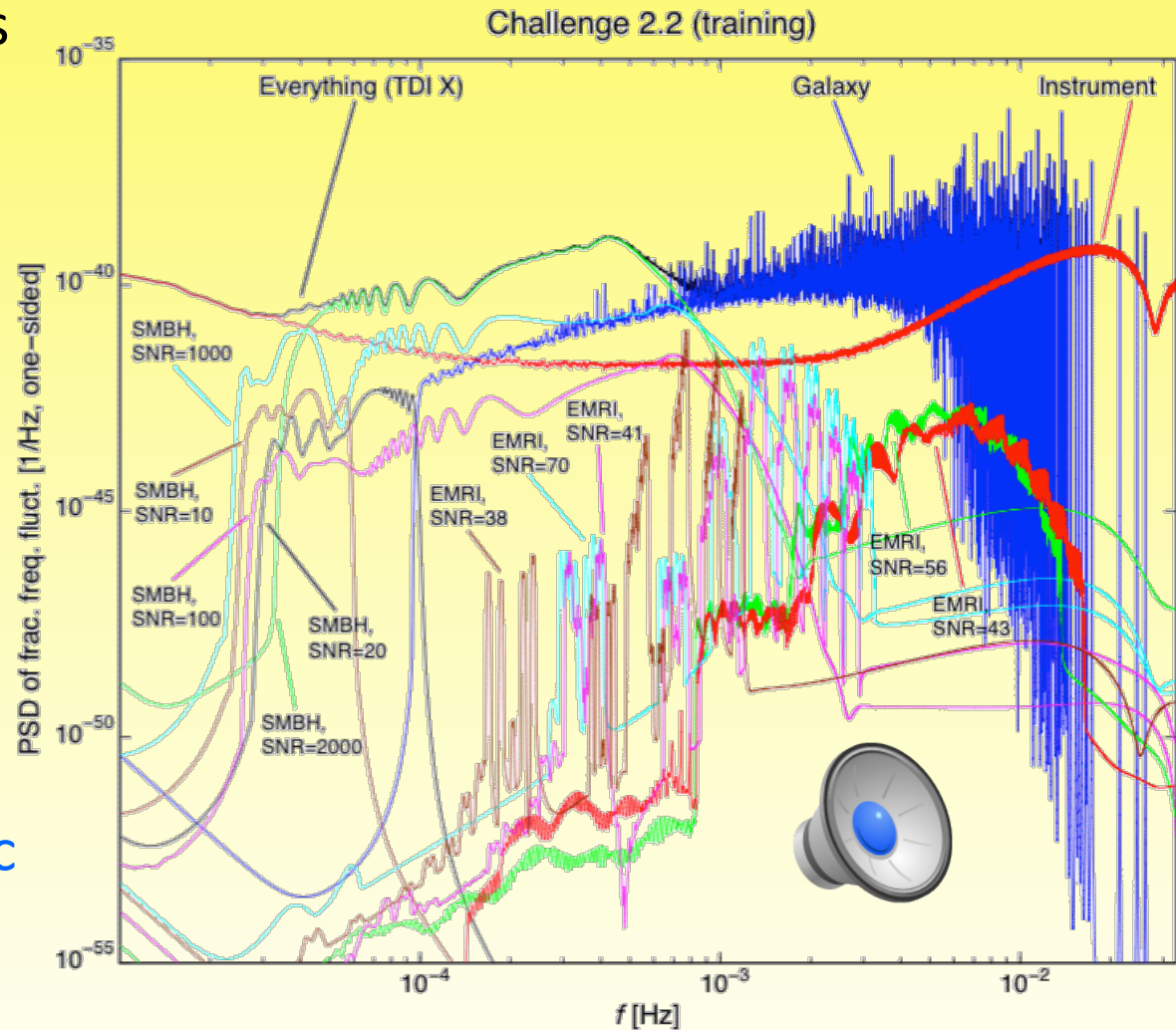
LISA Cosmology



LISA Mock Data Challenge (< 2010)



- Practicing data analysis on synthetic data
- Blind international challenge
- Full LISA data stream
 - Instrumental noise
 - 4 MBH events
 - 5 EMRI events
 - 26.1 million Galactic binaries
- Effective data analysis algorithms are needed!

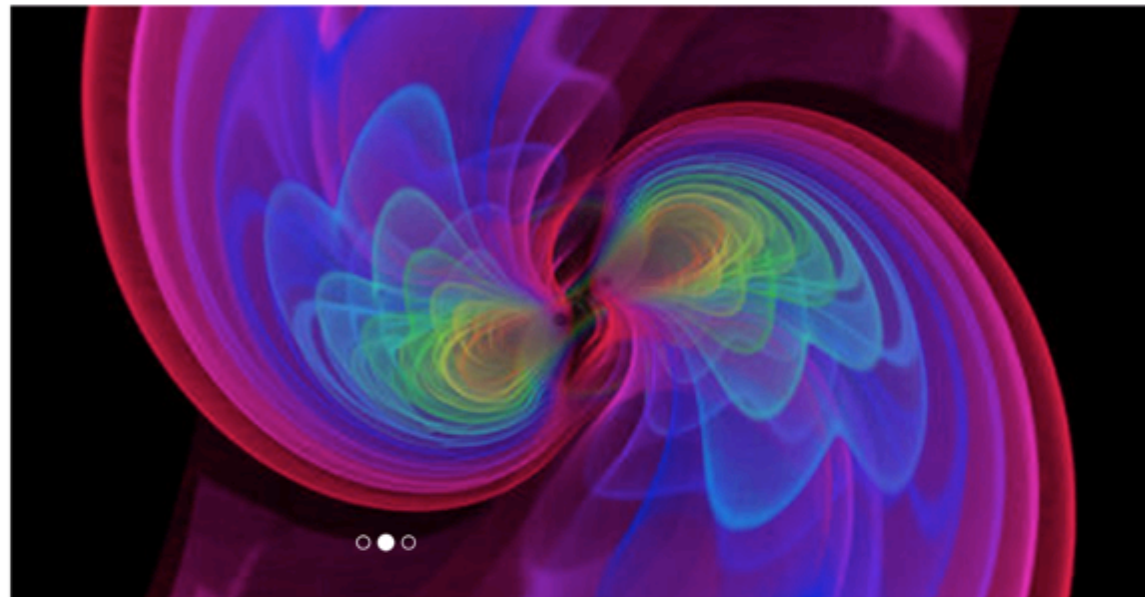
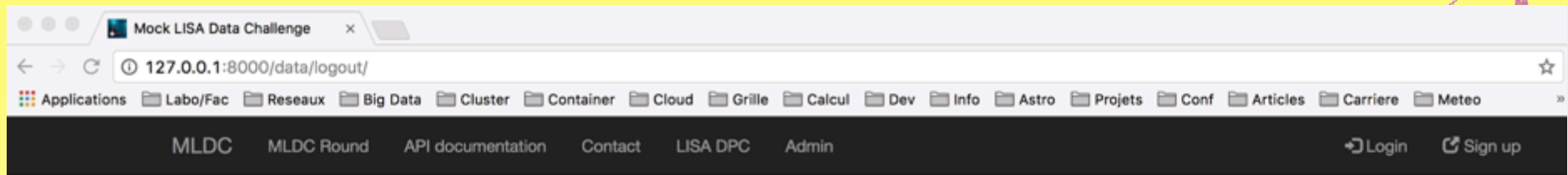


The new LISA Data Challenge (LDC)



- Resurrecting data challenges
- Project hosted under git-lab:
 - <https://gitlab.in2p3.fr/stas/MLDC> (sign up is required)
- Project oriented:
 - Each data set aims at particular data analysis problem
- Ultimate goal:
 - Build a robust data analysis pipeline for the LISA mission.
- Web-page will be open shortly for everyone to sign up for the challenge and download the simulated data set.

LDC webpage



Welcome on the MLDC website

In support of the Laser Interferometer Space Antenna (LISA) gravitational wave observatory, a Web site and application for the Mock LISA Data Challenge is provided.

You can find information of the MLDC on the [MLDC Round](#) page. Release data of the LISACode simulation code can be find at [Object list](#). A request form can be find at [Query](#). Contact information are at [Contact](#).

Data Processing Center (DPC)

MLDC Web application is part of the DPC of LISA. The goal of the DPC is to provide tools for code developpement and execution for the data analysis. The platform is reachable at [LISA DPC](#).

News

New dataset is provided...

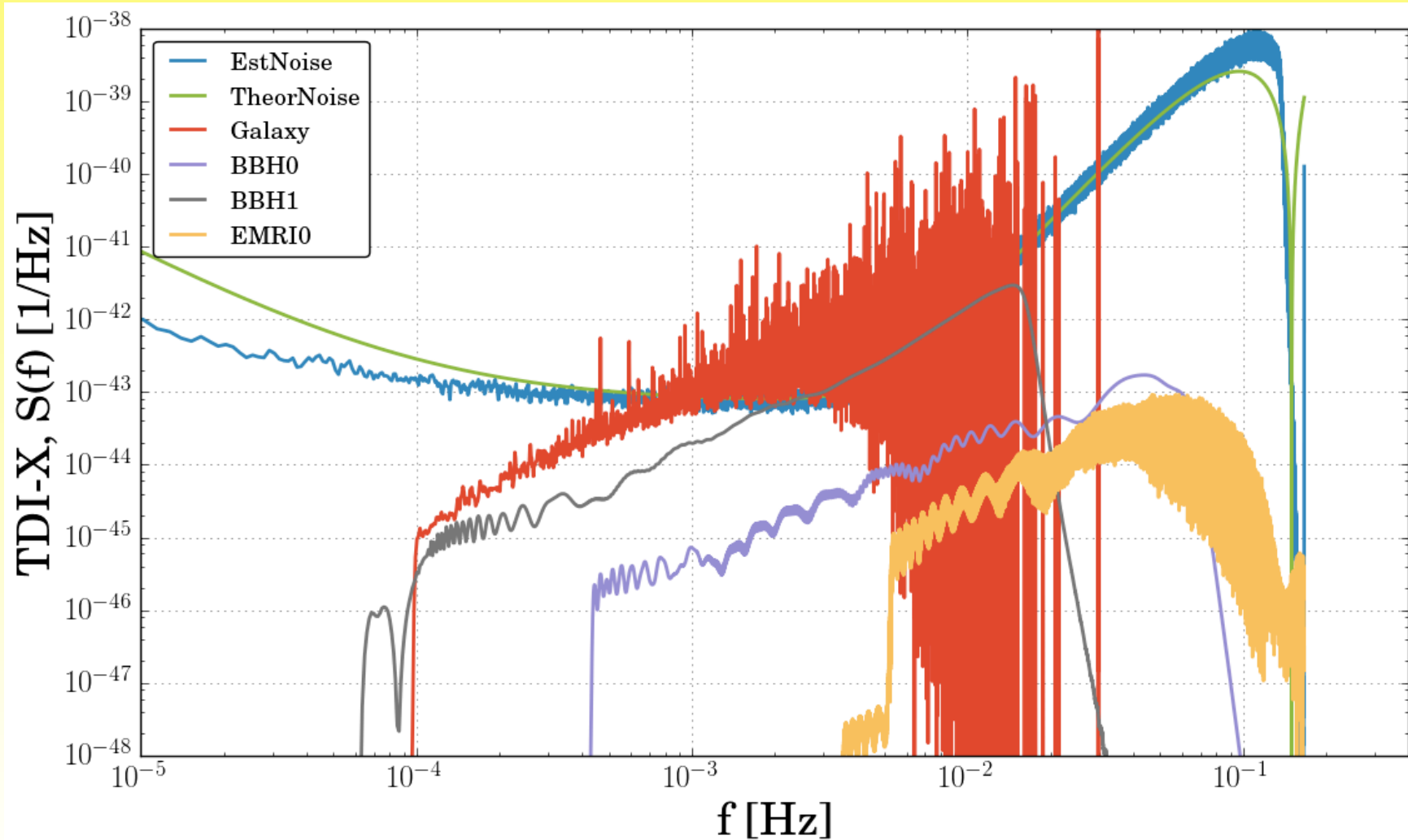
Website 1.0 is ready

Work in progress:
missing query form, formulary,
login registration.

First Data Release



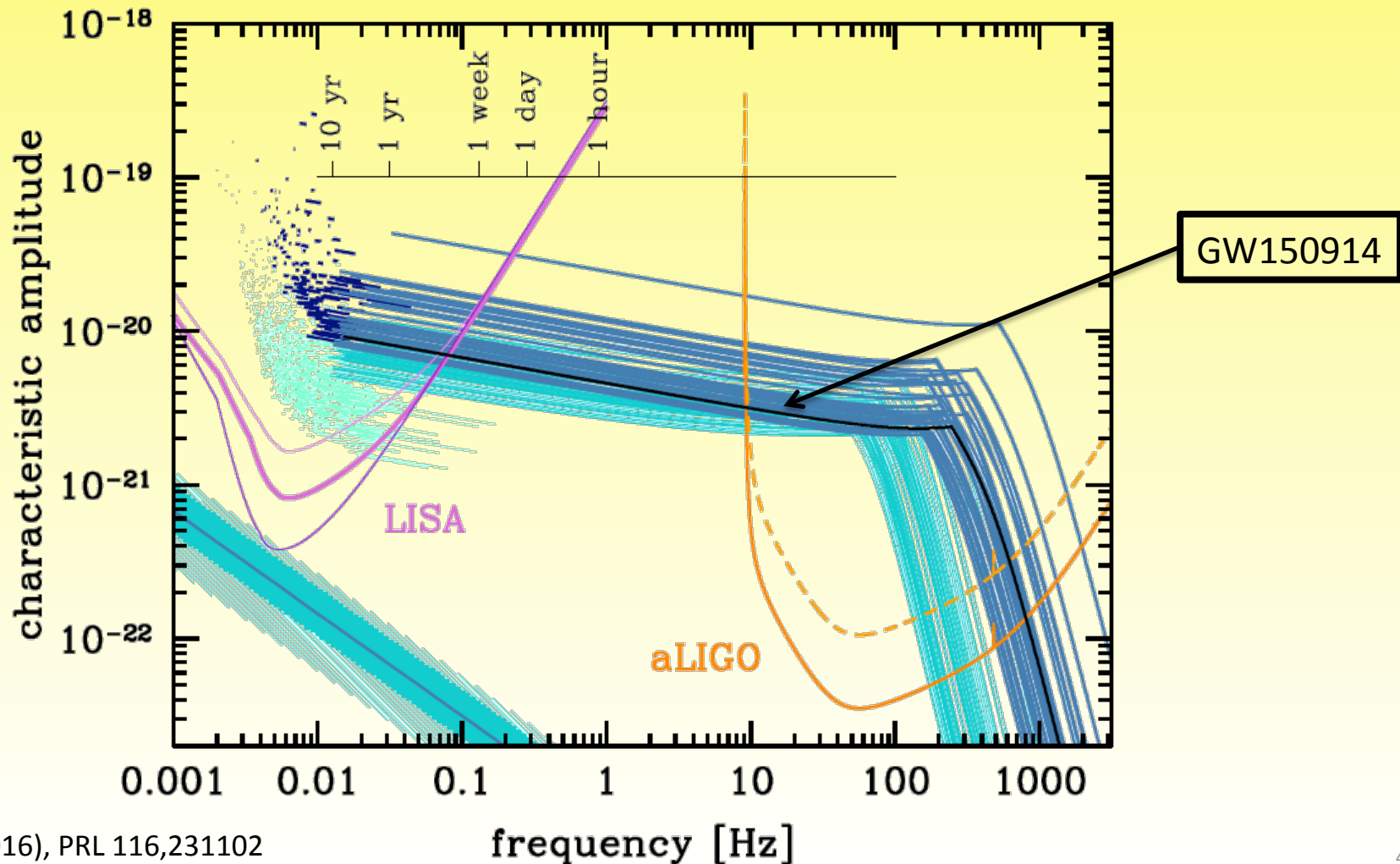
- First data release at the end of November



LISA: LIGO Event Predicted 10 Years in Advance!



- Accurate to seconds and within a square-degree!



ESA L2 and L3 Missions



- Call for Mission Concepts fall 2016
- Decision on L3 Adoption 2021
- Launch of L2 in 2028
- Launch of L3 in 2034
- **LISA shall be ready for an early launch!**

