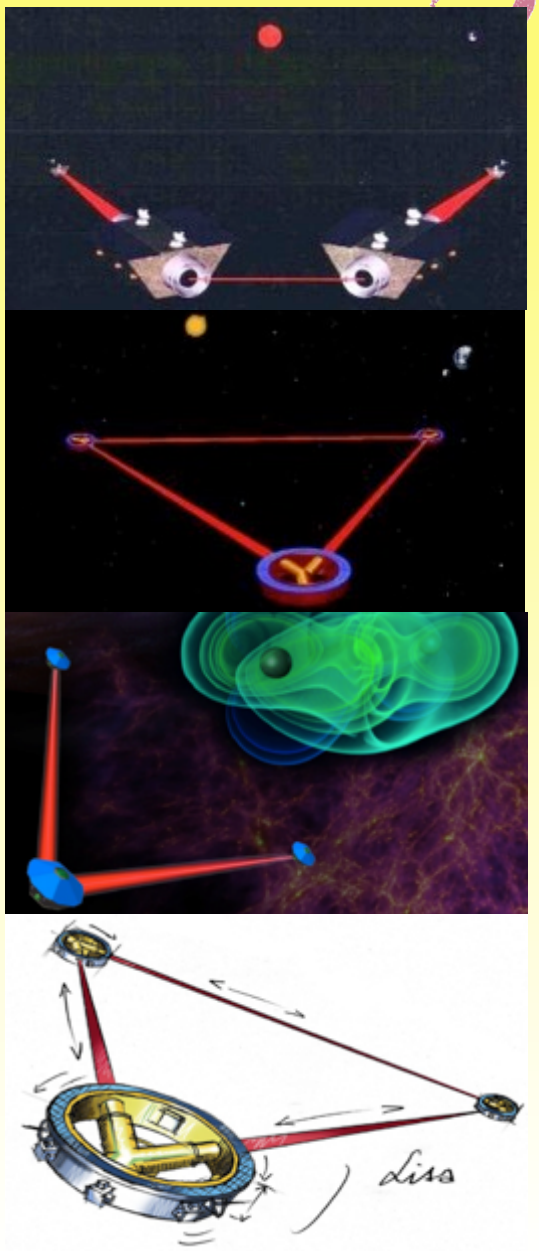
LISA:

Opens the low-frequency gravitational universe !

Selected! June 20, 2017: ESA-L3!

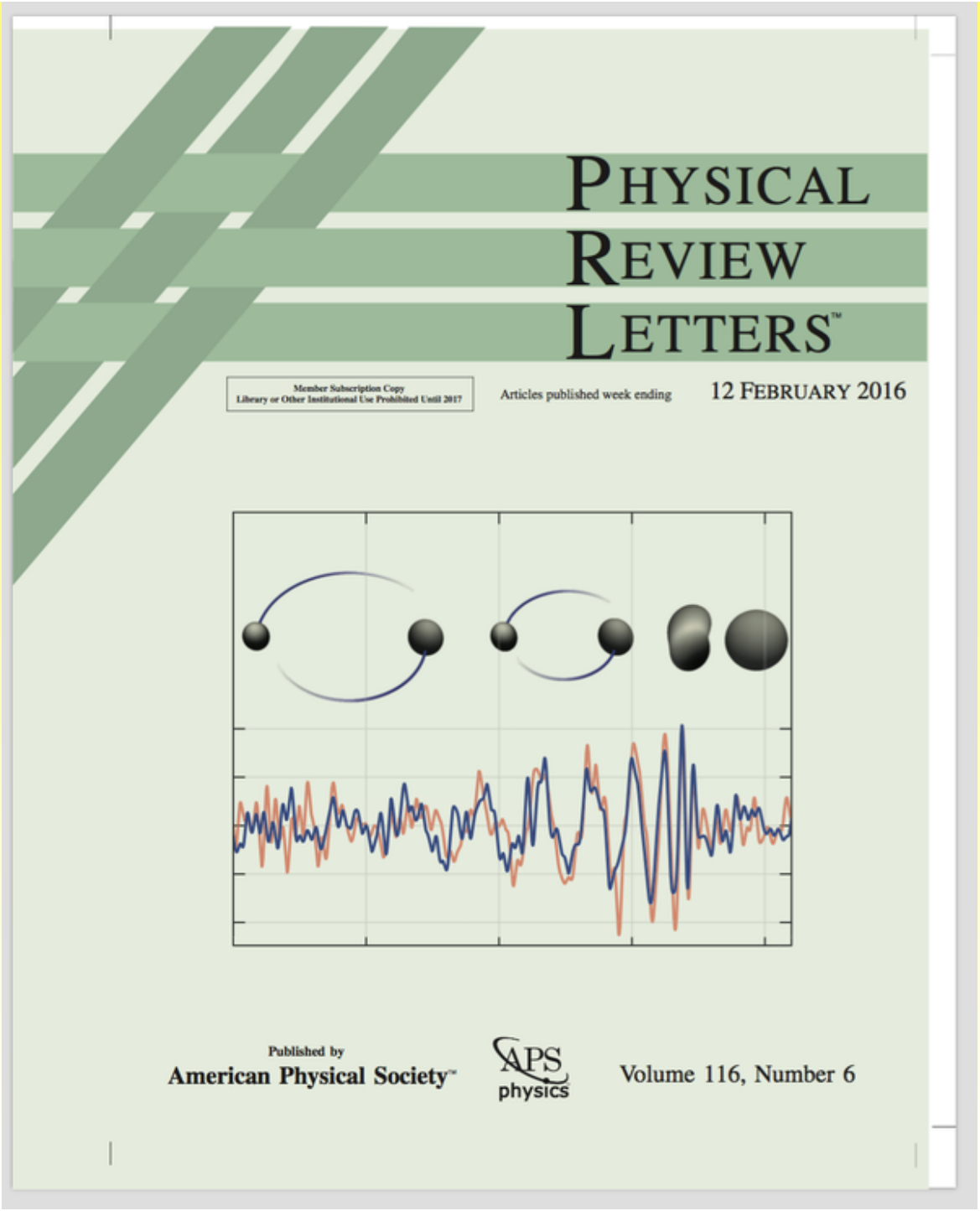
LISA: A Mature Concept

- 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



We had to wait a long time!
But then came 2015/2016..

- And two things happened!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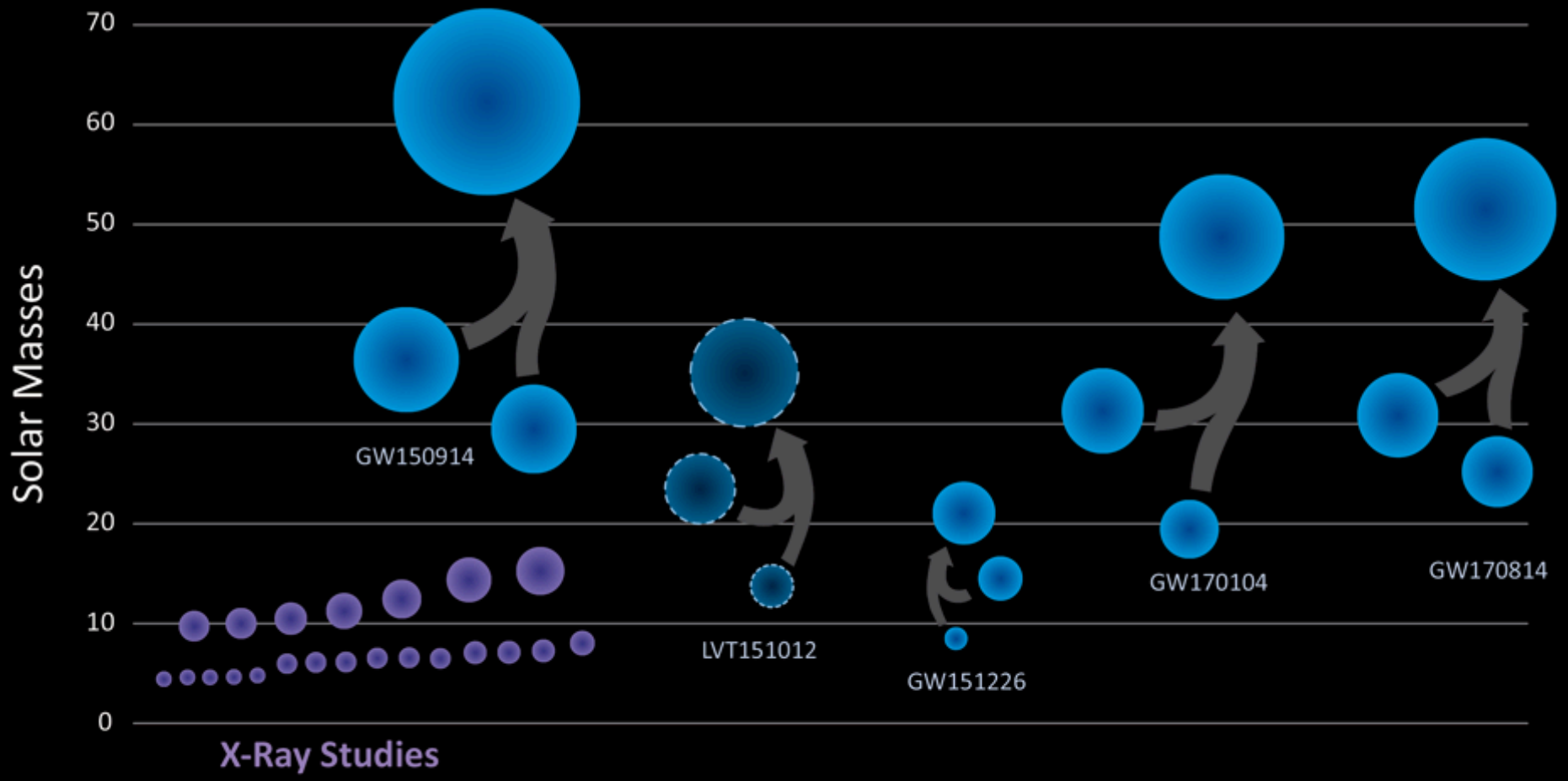
12 FEBRUARY 2016
Published by
American Physical Society™
APS
physics
Volume 116, Number 6

Black Holes every Month!



Credit: LIGO/Caltech/Sonoma State (Aurore Simonnet)

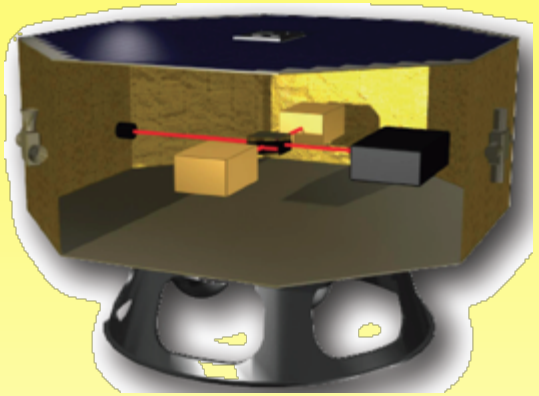
LIGO/VIRGO

LISA Pathfinder

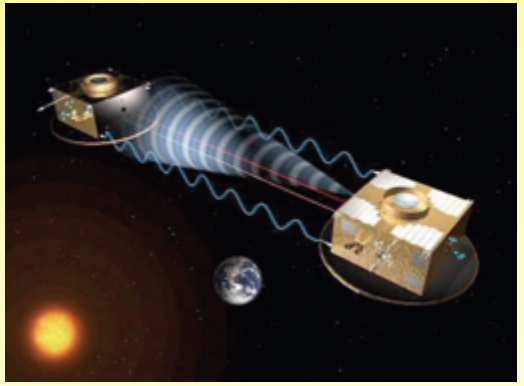
- Testing LISA technology in space!

First Proposed in 1998 as ELITE

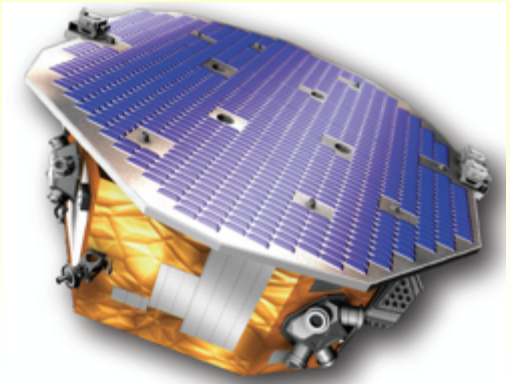
- European LIsa TEchnology Satellite



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

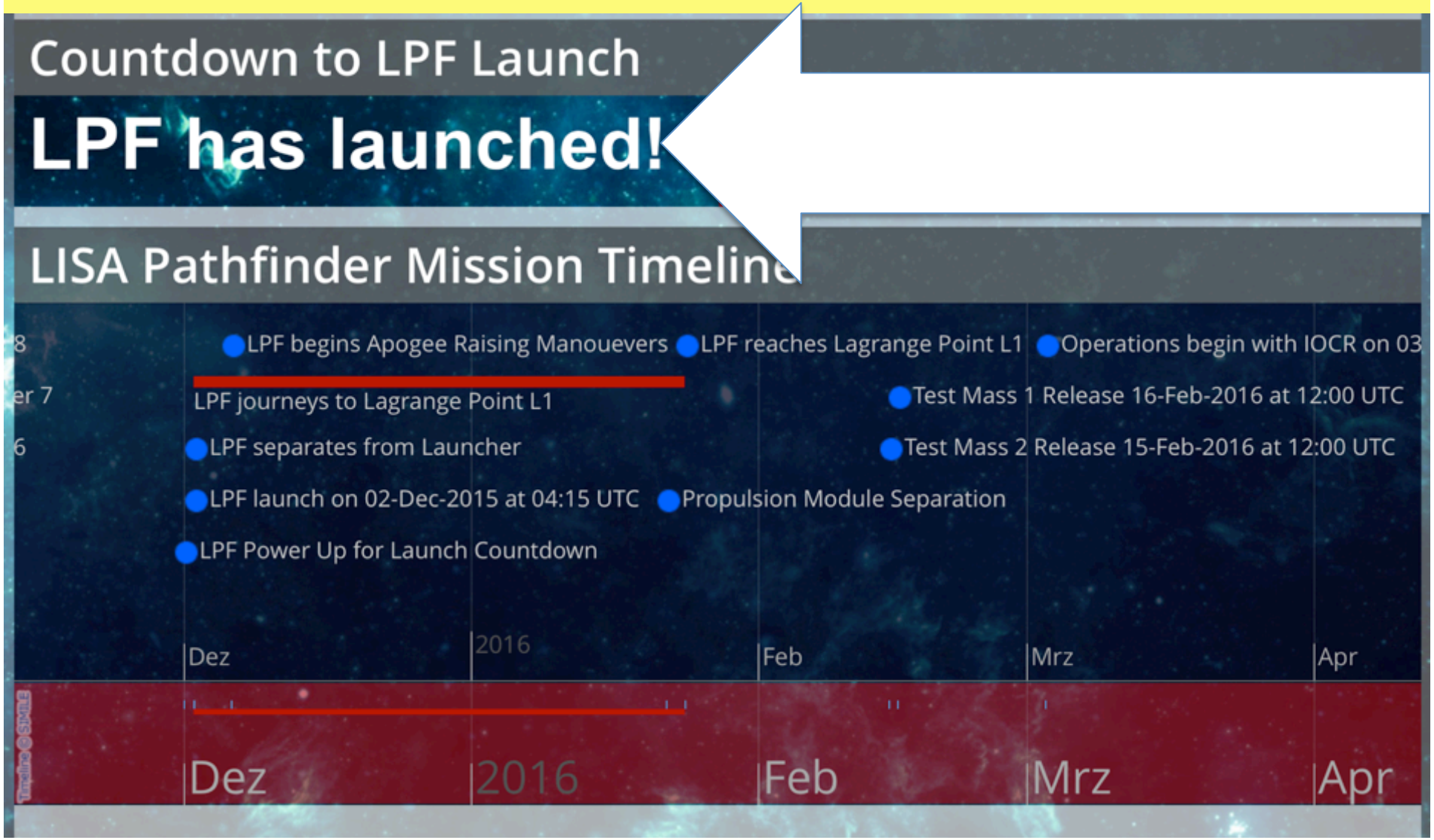


- Descoped to LISA Pathfinder
  - Darwin demo cancelled



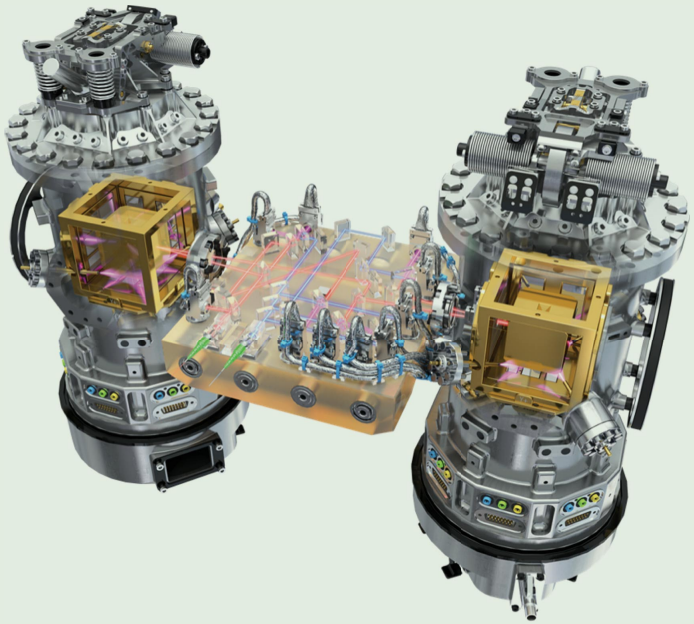

17 years later!
September
2015:
Spacecraft is
completed!
lisa pathfinder
AIRBUS
DEFENCE & SPACE
esa
ABG
S
AIRBUS

100 Years since GR Publication: Dec. 2, 2015



PHYSICAL REVIEW LETTERS

Articles published week ending 10 JUNE 2016



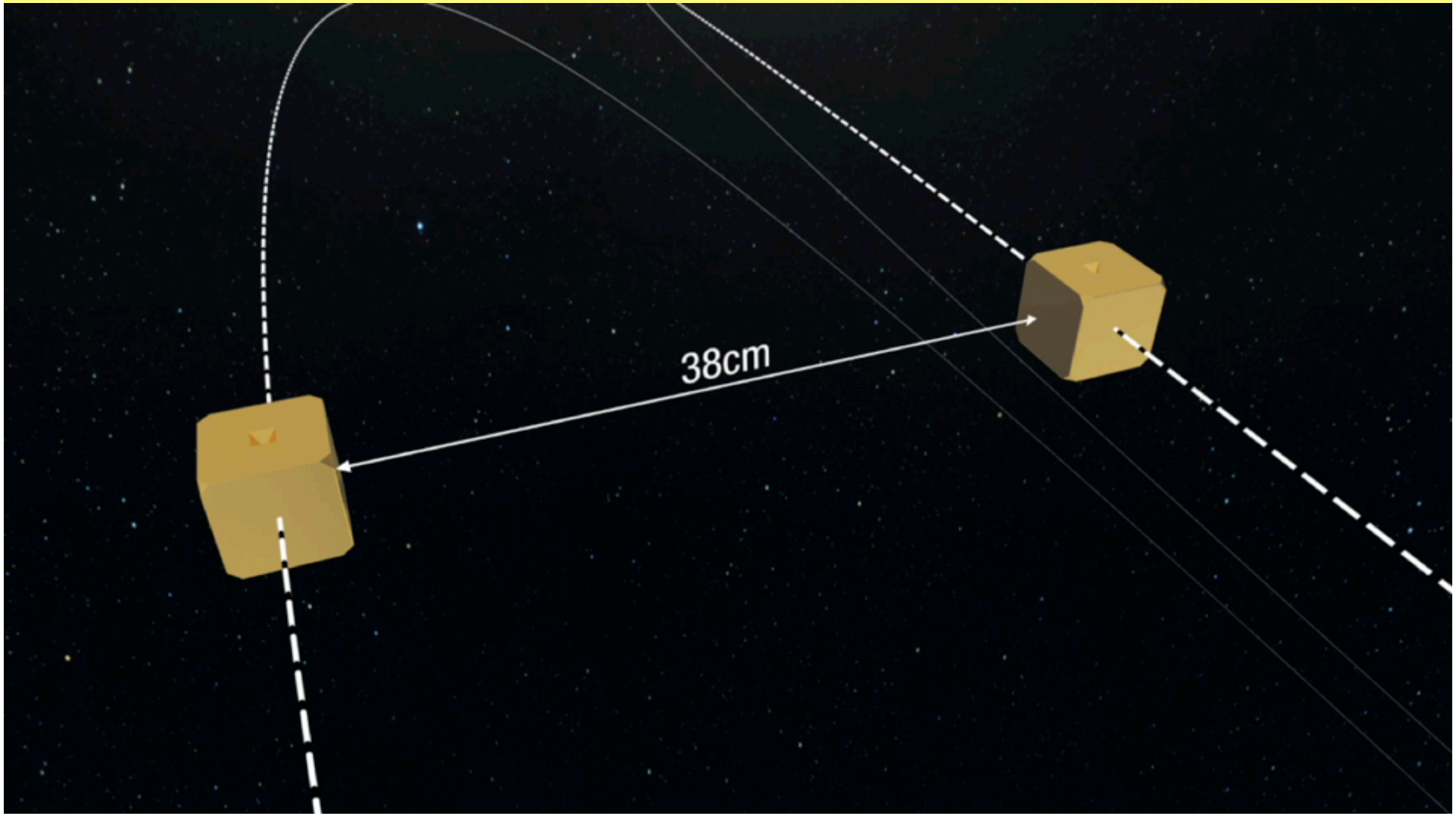
Published by
American Physical Society

APS physics

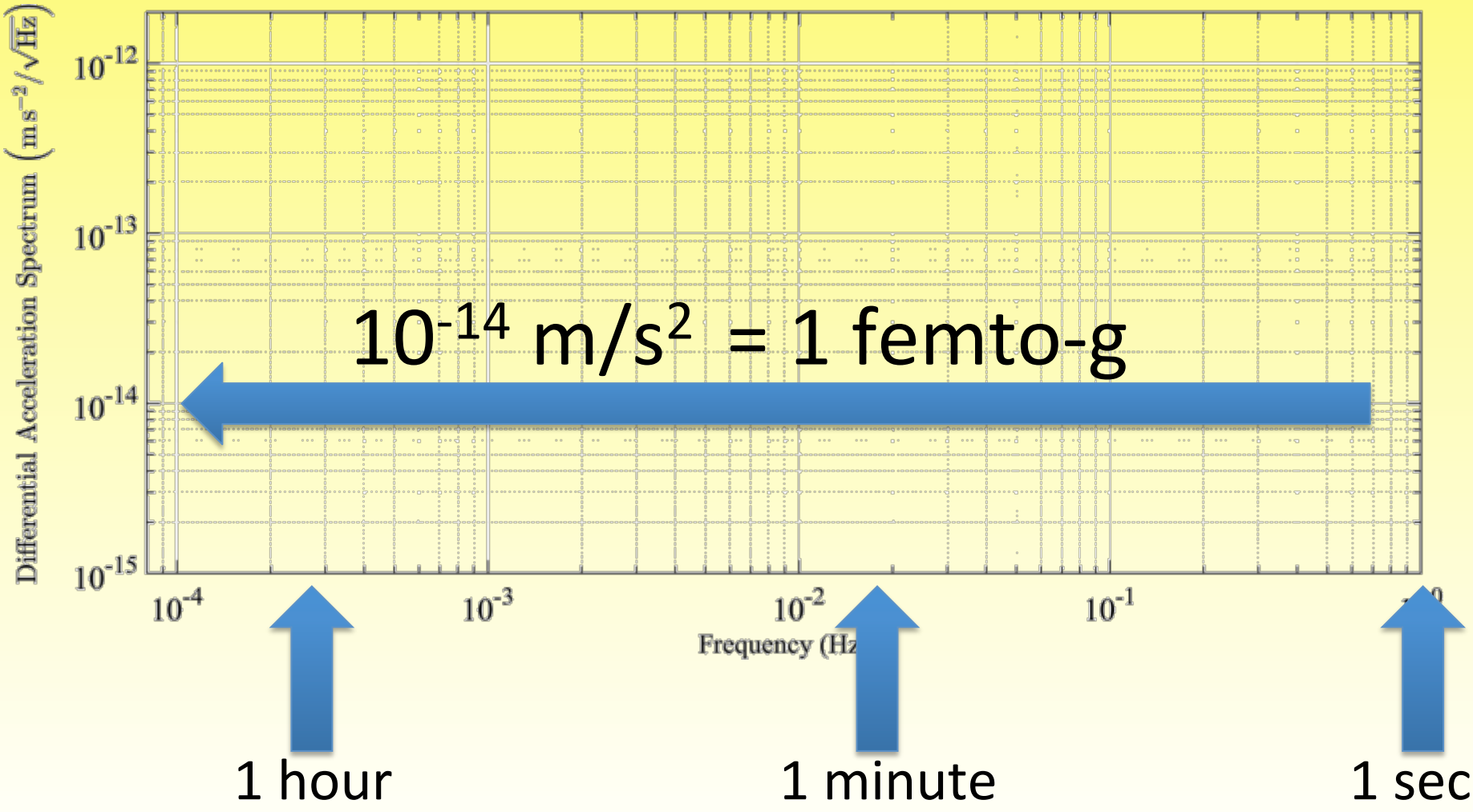
Volume 116, Number 23

The Stillest Place in the Universe!

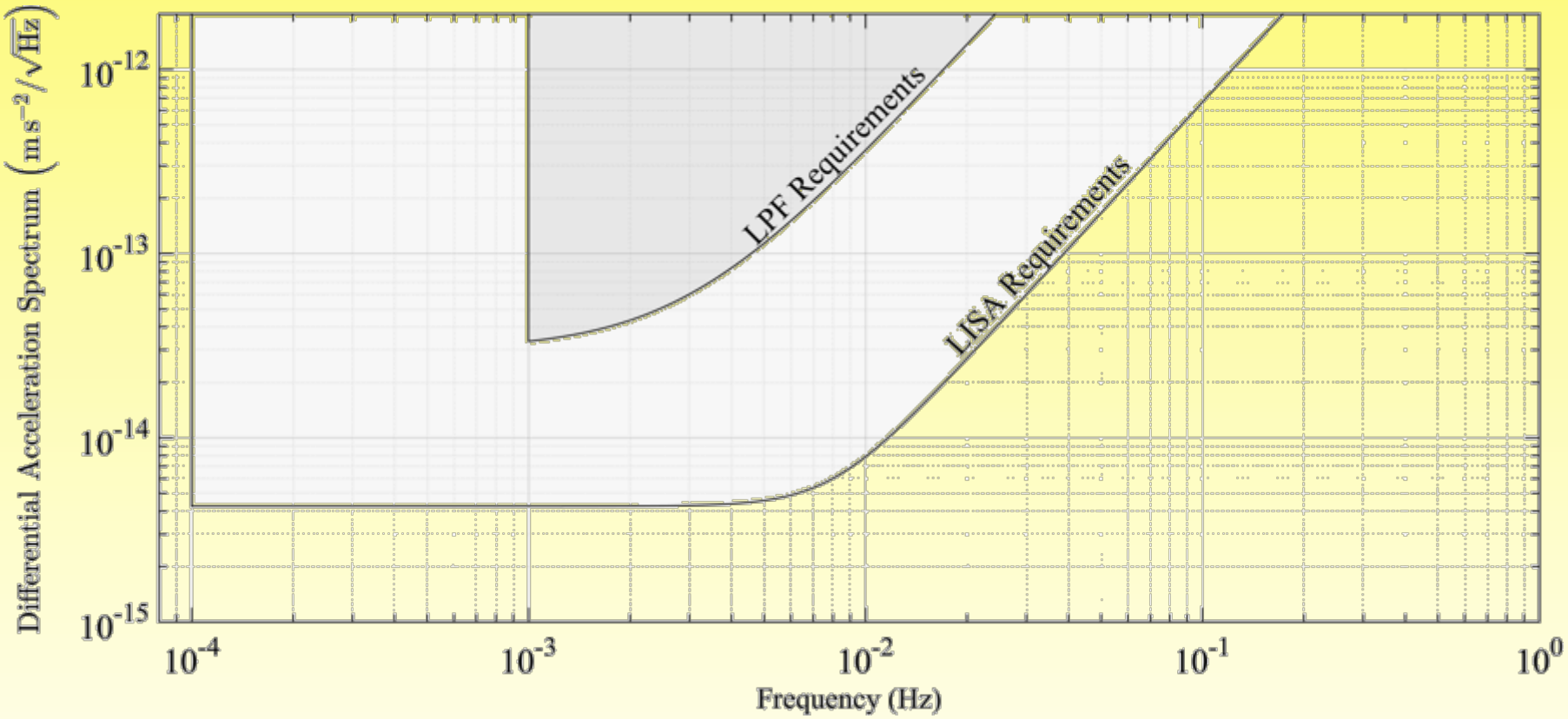
- More sensitive than the weight of a virus!



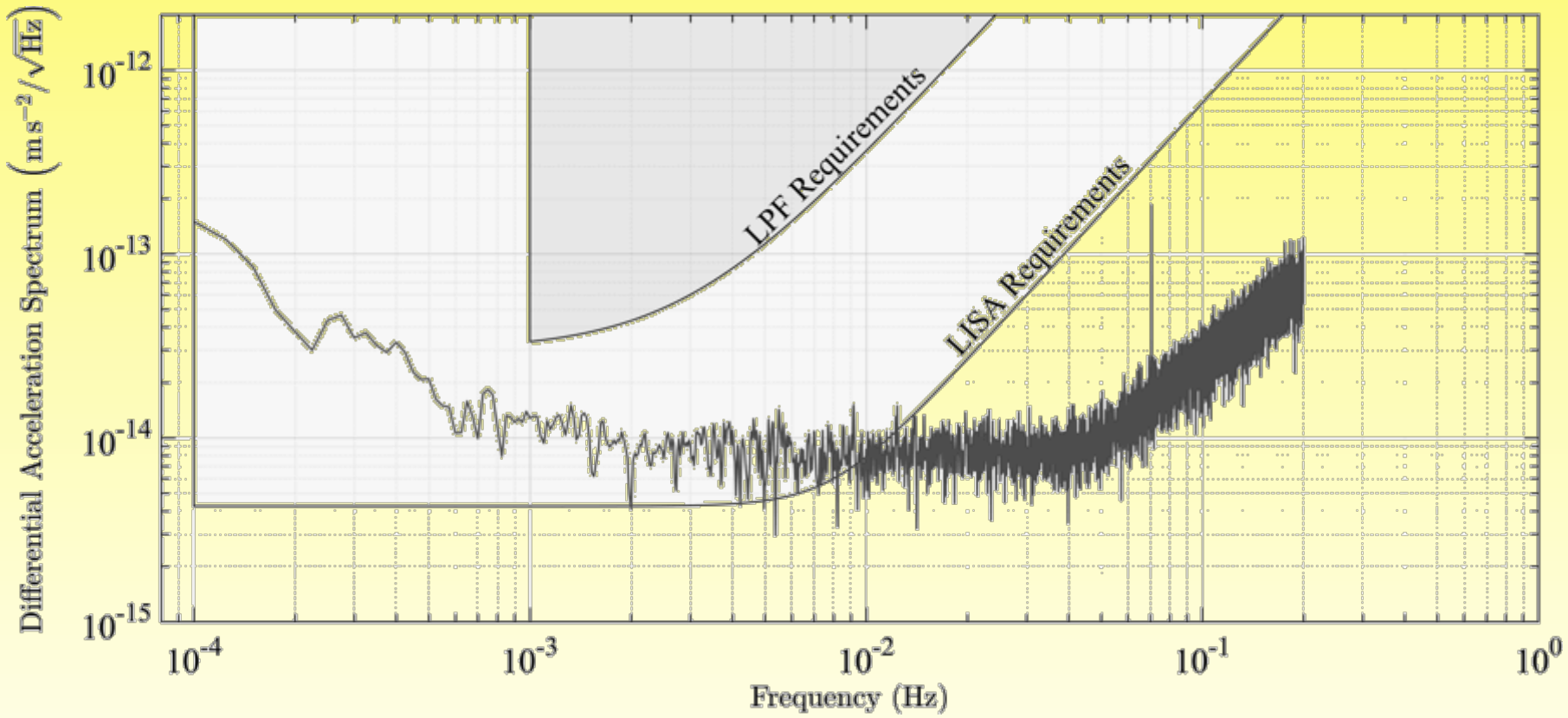
Acceleration Spectrum



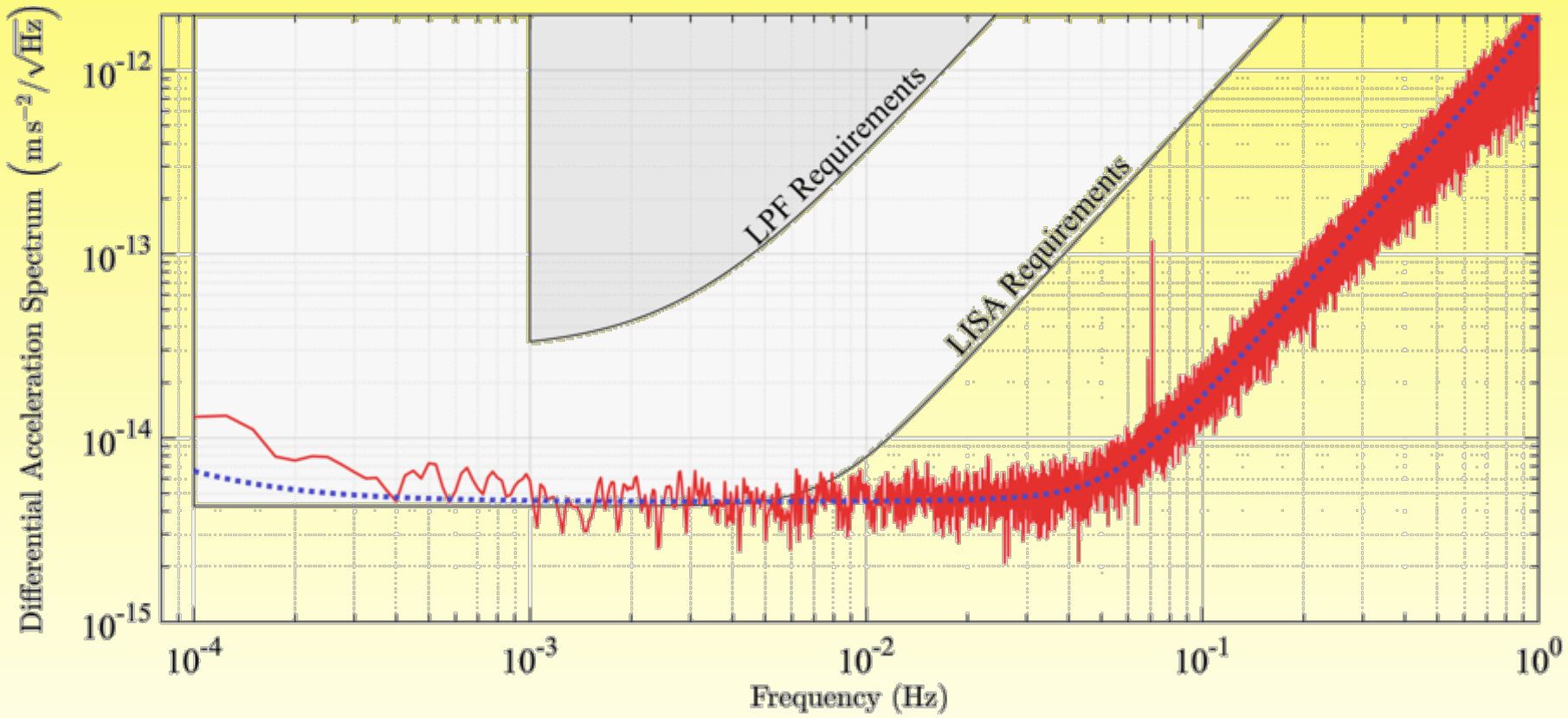
LISA and LPF Requirements



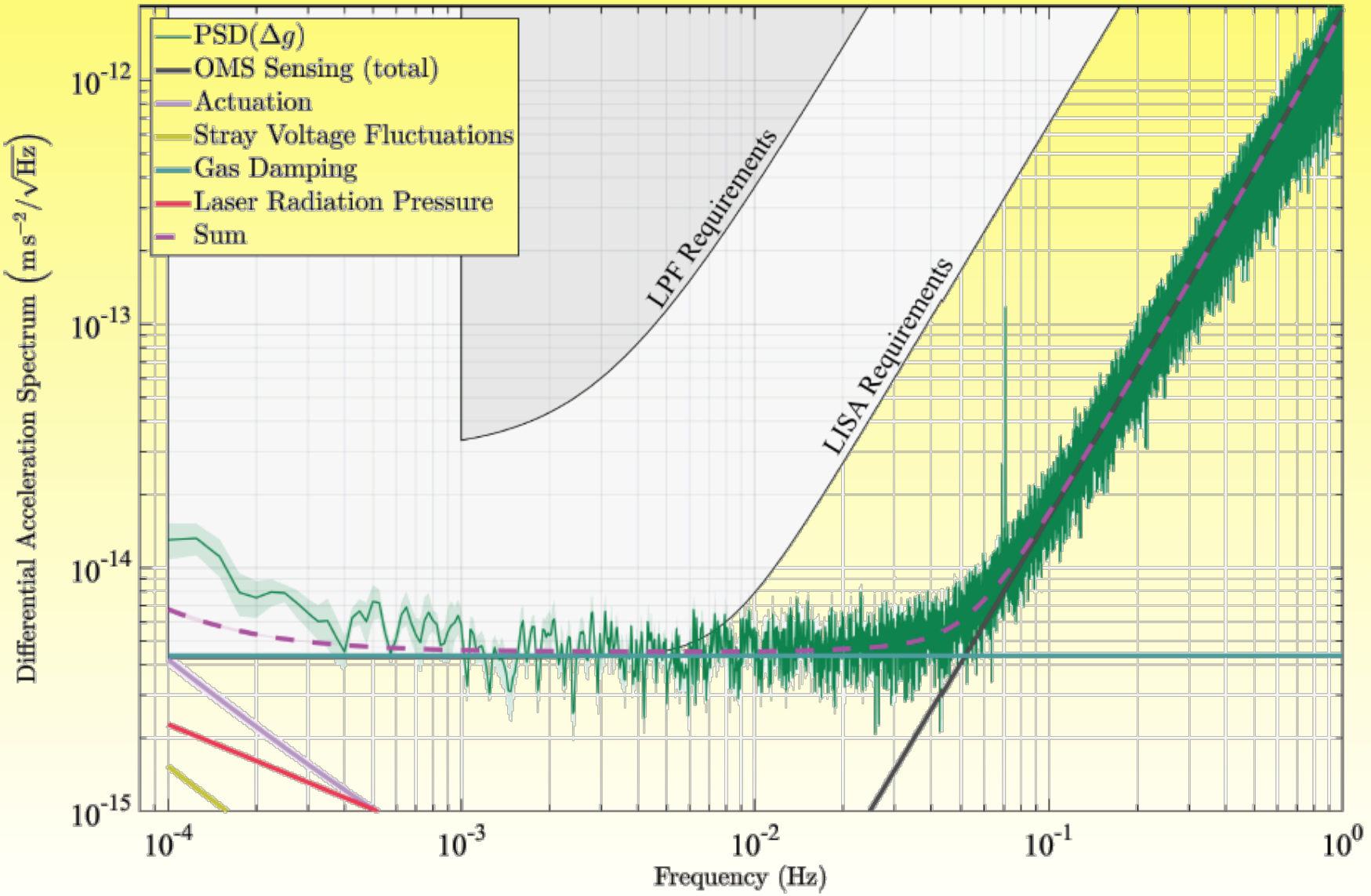
First Day of Operations: March 1, 2016



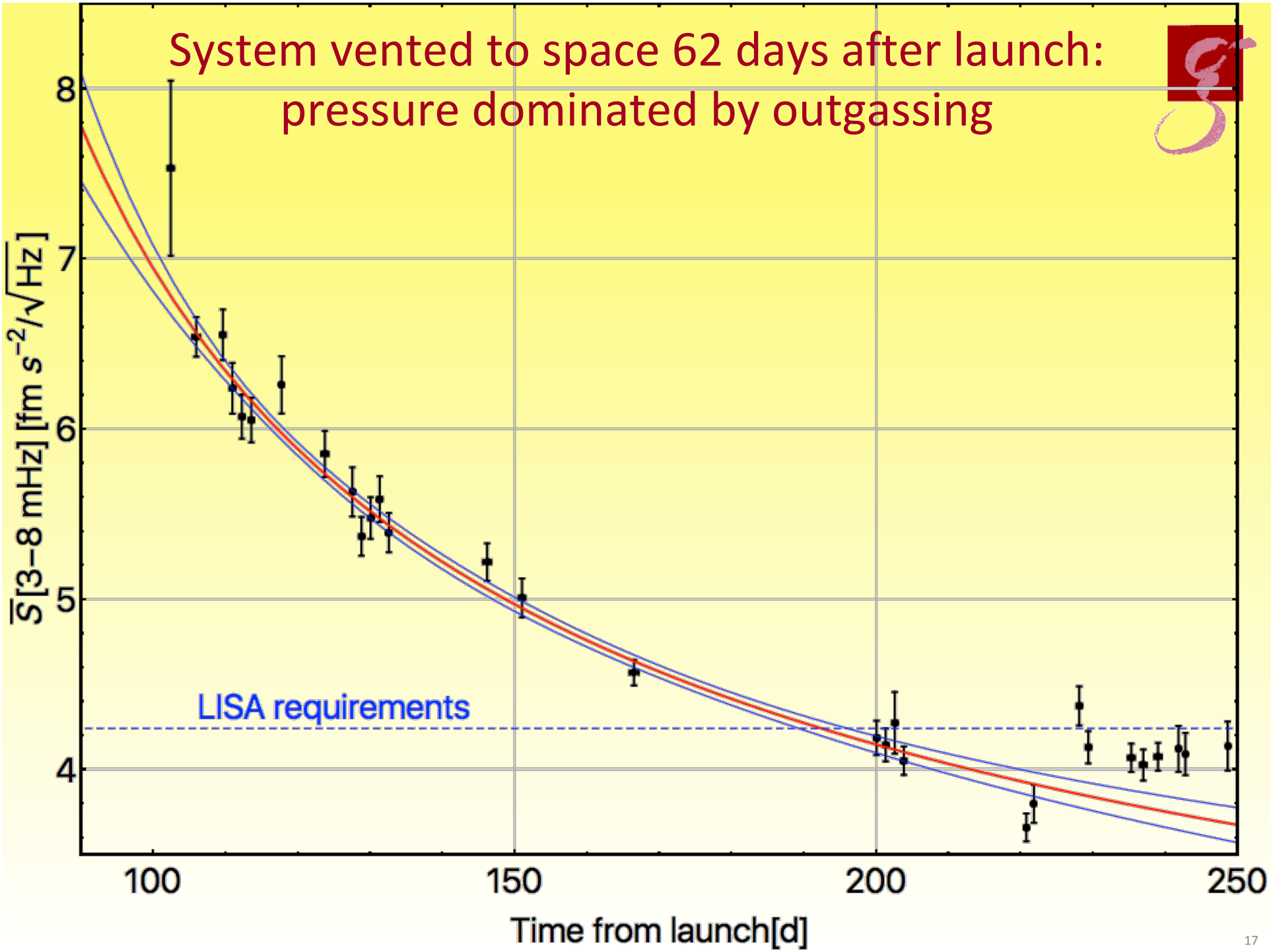
May 16, 2016, System Optimized Investigations Ongoing



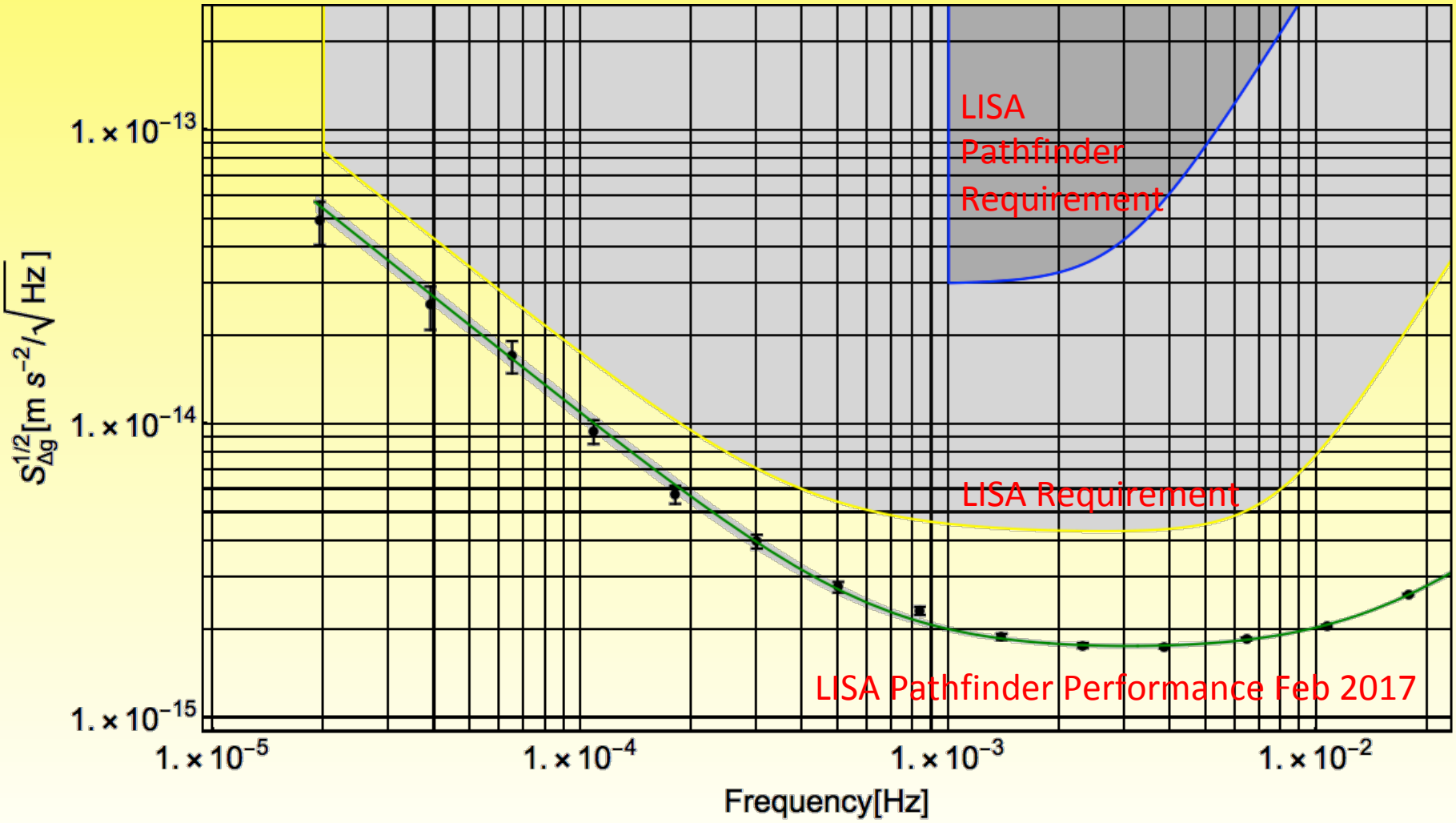
Noise Sources



System vented to space 62 days after launch: pressure dominated by outgassing

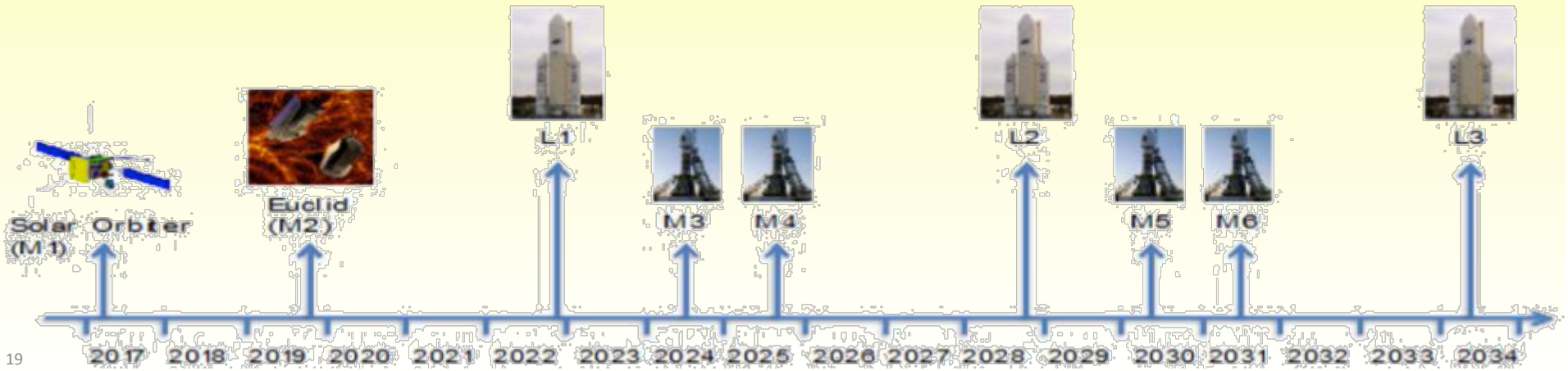


LISA Pathfinder shows: LISA Works!

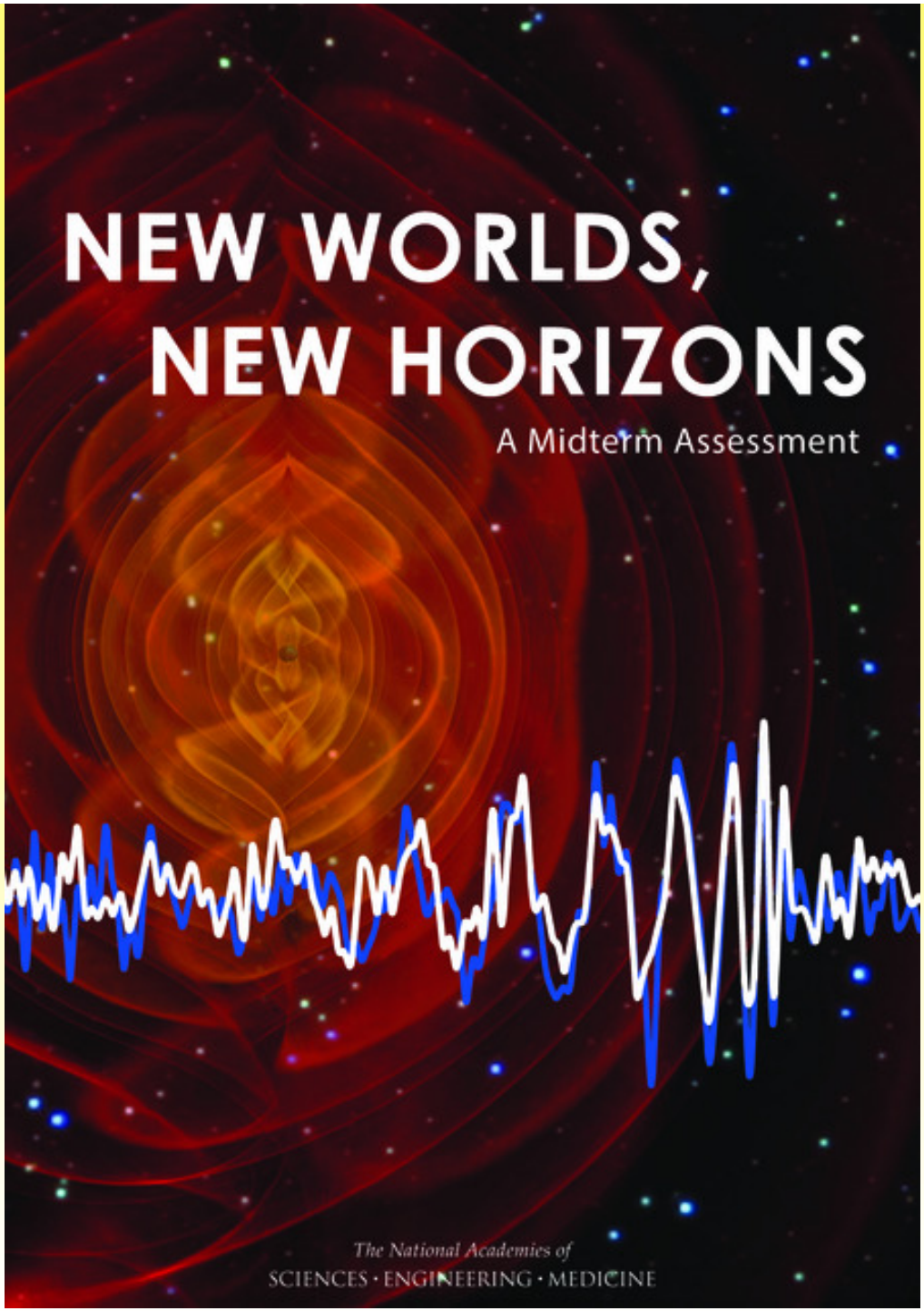


ESA L2 and L3 Missions

- Call for Mission Concepts fall 2016

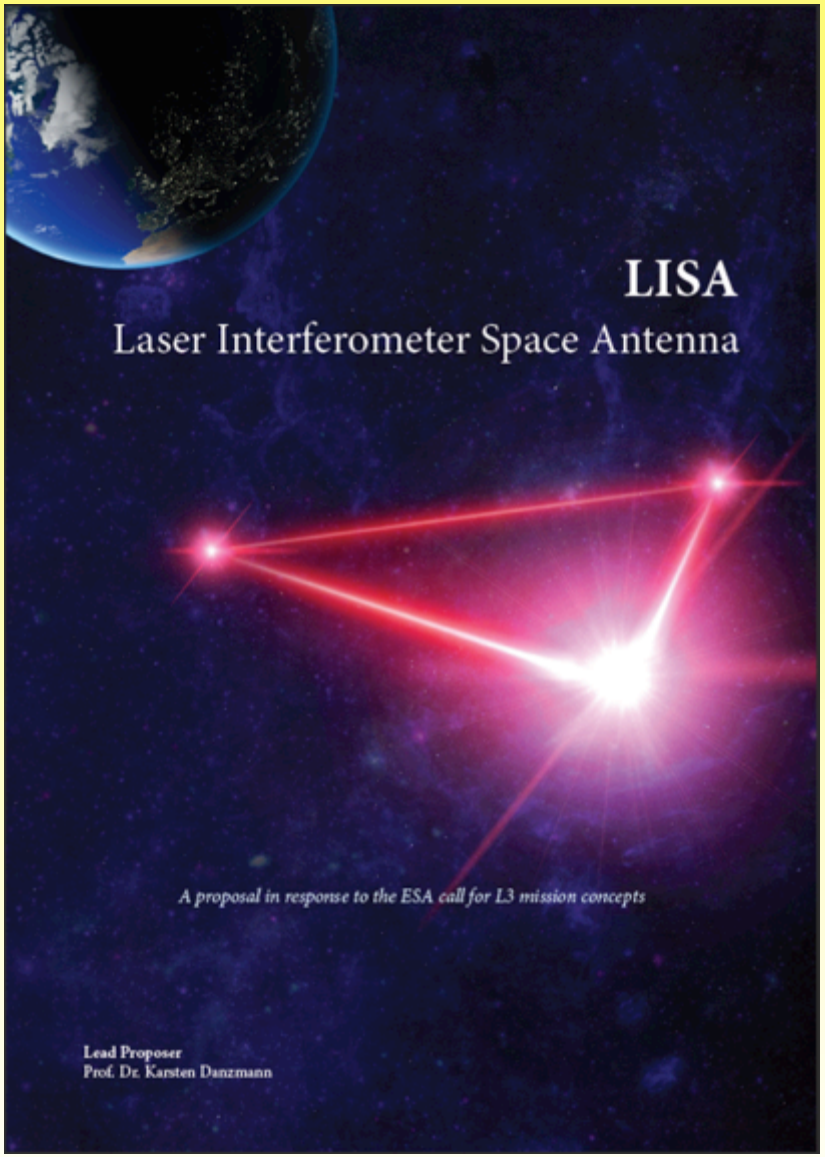


NASA is back in LISA!



LISA Mission Concept Document

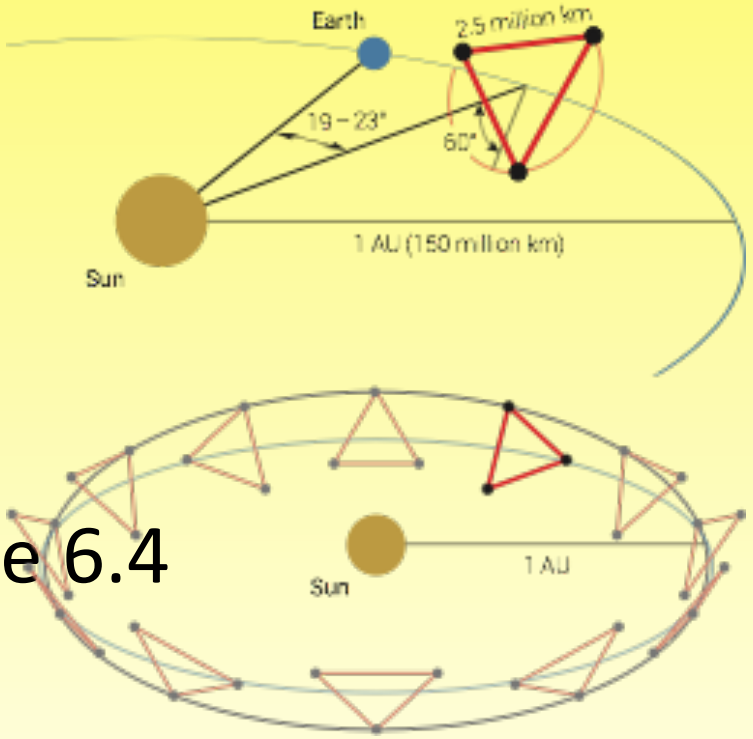
- Submitted on January 13th, 2017
- The LISA Consortium: 12 EU Member States plus the US !



www.elisascience.org/files/publications/LISA_L3_20170120.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_∞ = 260 m/s
  - Propulsion module and S/C composite



ESA SPC selected LISA as L3 !

cosmic vision

esa

ESA | SCIENCE & TECHNOLOGY | COSMIC VISION

Missions
- Show All Missions

Cosmic Vision 2015–2025
- Cosmic Vision
- Candidate Missions
- M-class Timeline
- L-class Timeline

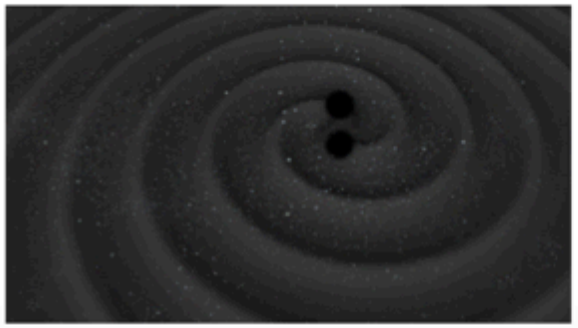
Cosmic Vision themes
- The Hot and Energetic Universe
- Planets and Life
- The Solar System
- Fundamental Laws
- The Universe

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

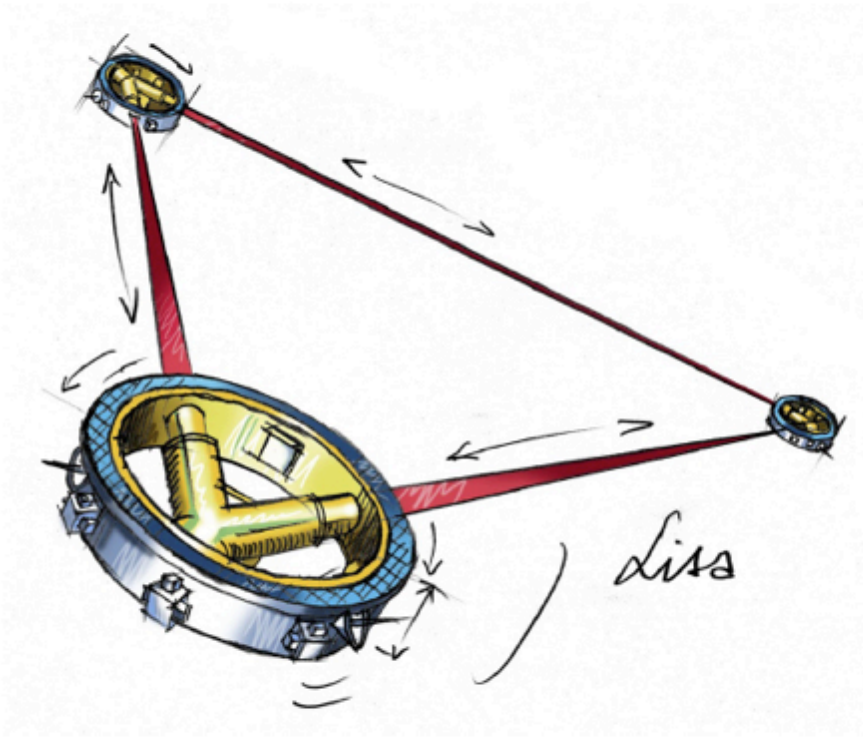
Start of Phase 0: CDF Study

LISA
Study Introduction

Systems

Session 1
ESTEC, 08-03-2017

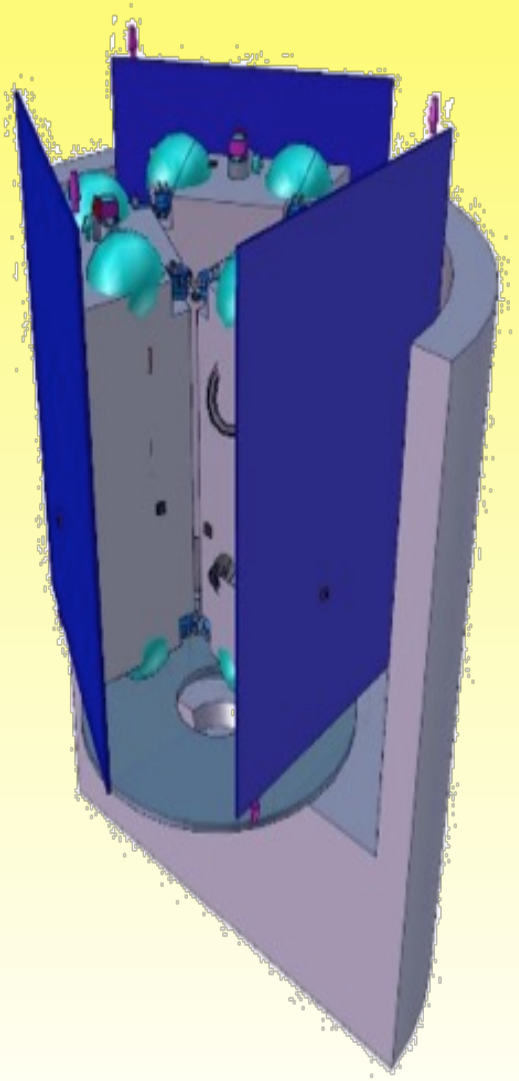
Prepared by the CDF* Team



(*) ESTEC Concurrent Design Facility

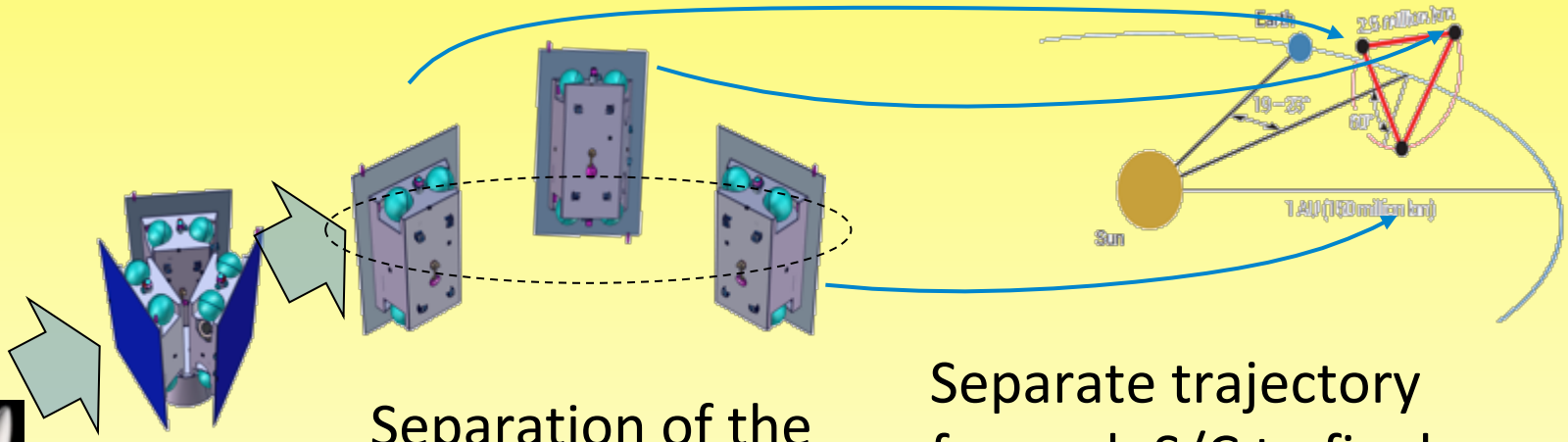
LISA Phase 0 System Study

- 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

Governance

- Phase-0 Study concluded
- Kick-off for Phase-A in Spring
- Must have new governance structure for Consortium in place before Phase-A Kick-off
- Lot of background discussions and f2f meetings
- Consensus-oriented preparation
- Consensus-based planning
- Governance described in Management Plan

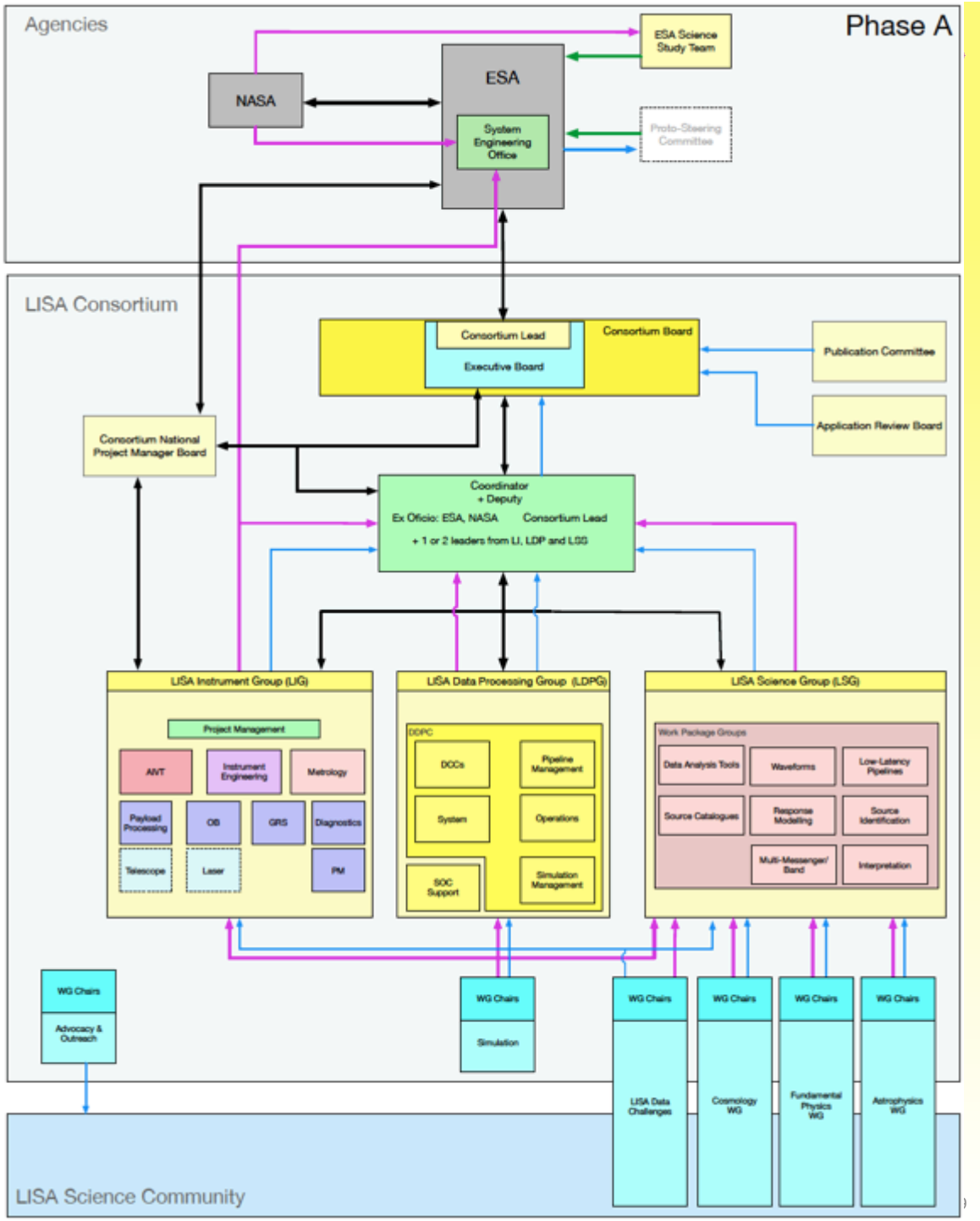
Laser Interferometer
Space Antenna

Ref : LISA–LCST–MIS–PL–001	
Issue : 1	Revision : 4
Date : 2018/03/20	Page : 1/ 25

LISA Consortium Management Plan

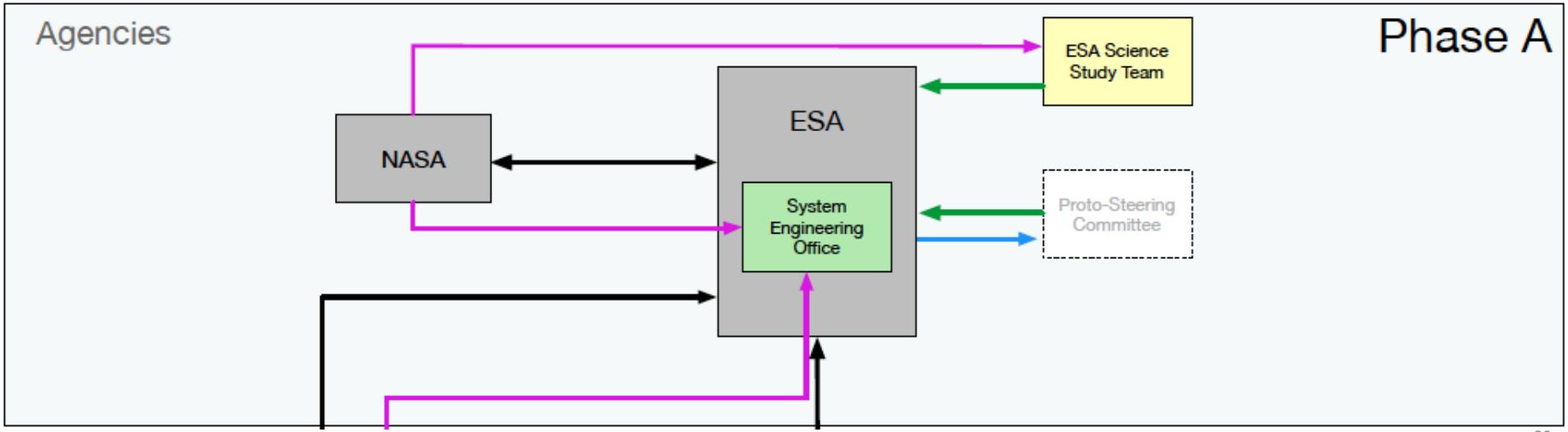
N/Ref :	LISA–LCST–MIS–PL–001
Title	**LISA Consortium Management Plan**
Abstract	LISA Consortium Manangement plan.

Consortium Structure for Phase-A

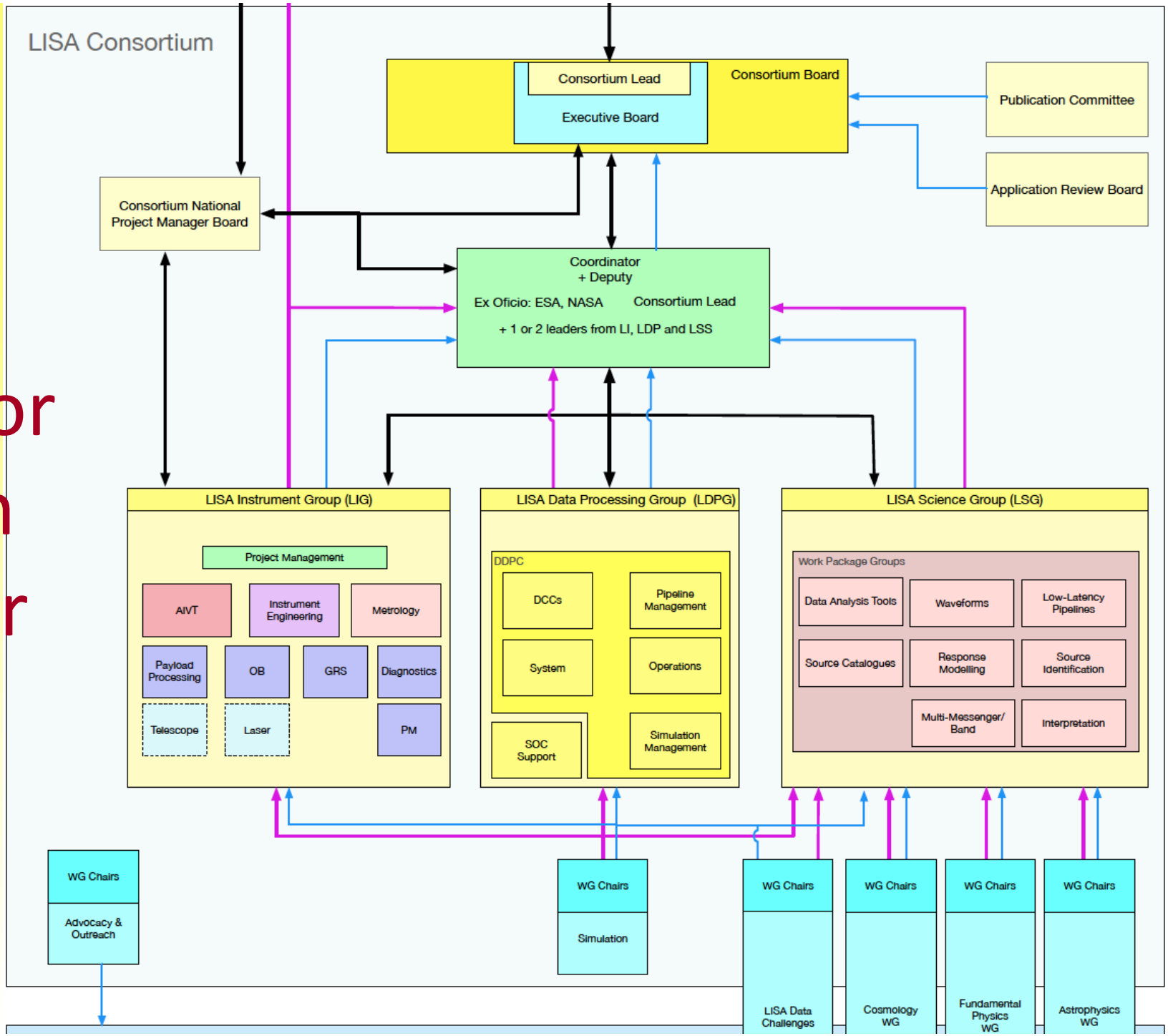


Agency Layer

- ESA-led, NASA smaller partner, direct interaction
- ESA-appointed Science Study Team (with NASA participation) advises ESA about Science Requirements and their fulfillment
  - Partial overlap with Consortium leadership
- Strong central System Engineering office sets requirements deep down into payload
- Consortium supports central SE office, through advice and people

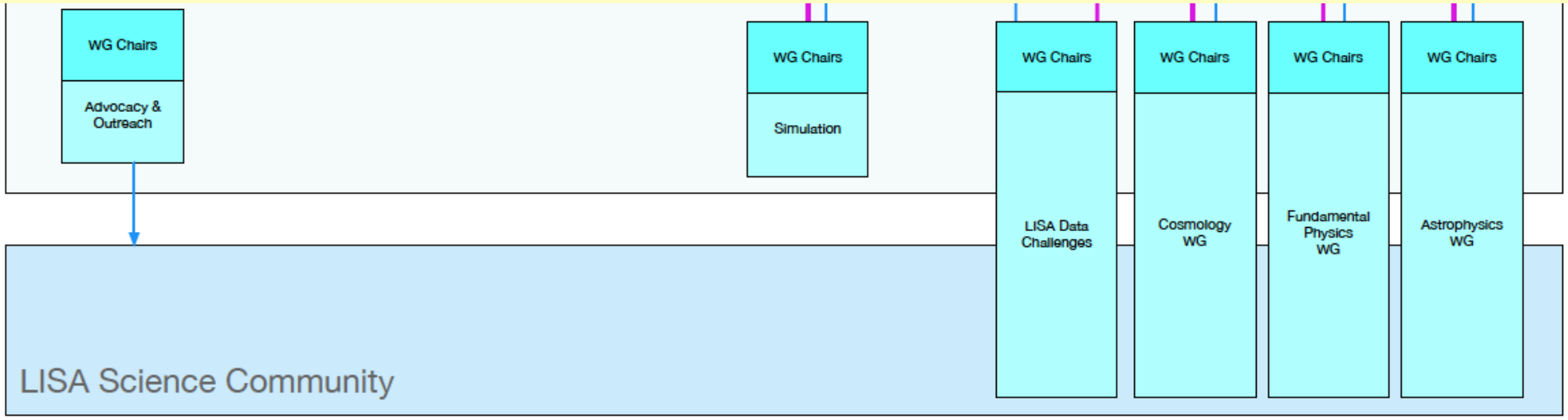


Consortium Layer



Community Layer

- Working Groups are entry points into Consortium
- Led by WG chairs who are Consortium members
- Some members are in Consortium
- Others in wider Community



Consortium Membership Application

- Formal process based on commitment
- Examples:
  - contribution of flight hardware for Consortium deliverables
  - performing laboratory tests of parts of the LISA instrument
  - development of data analysis pipelines, or parts thereof
  - commitment to one or more work packages
  - performing a coordination role.
- Commitment specified in web-based MOU
- Yearly report and self-review, new MOU Draft
- Screening by Application Review Board
- Appeal to Consortium Board

Process has Started

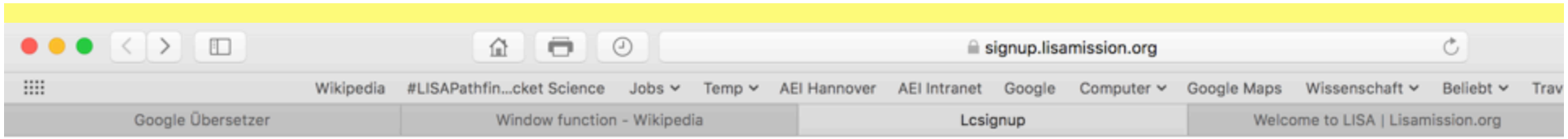
- Should be complete by May

Laser Interferometer
Space Antenna

Ref : LISA-LCST-MIS-PR-001	
Issue : 1	Revision : 0
Date : 2018/03/20	Page : 1/ 8

LISA Consortium Application Process

N/Ref :	LISA-LCST-MIS-PR-001
Title	**LISA Consortium Application Process**
Abstract	A description of the LISA Consoritum application process.



lisa

Consortium application form

Name

e.g. Albert Einstein

Affiliation

e.g. AEI Hannover

Application type

- ◯ Group
- ◯ Associate

Application document

Datei auswählen Keine Datei ausgewählt

(Spreadsheet format preferred, PDF will also be accepted.)

Comments

(optional)

Application document

Datei auswählen Keine Datei ausgewählt

(Spreadsheet format preferred, PDF will also be accepted.)

Comments

(optional)

I have read and agree to the rights and duties as outlined in the Consortium application process

Send application

Step by step

1. Download the application template below
2. Download and read the Consortium application process document linked below
3. Fill out the application template
4. Fill out this application web-form and attach completed application document
5. Submit application and wait for confirmation E-Mail

If you run into issues or have questions with regards to your LISA consortium application please contact us

Your application will be reviewed and you will be notified of the outcome in due course.

The following documents are available for reference when indicating areas of commitment:
Consortium Management Plan
Consortium Application Description
Data Analysis Work Packages

An application template is available here.
Example draft applications are available here and here.

Consortium Application Status (as of April 19, 2018)

- So far received 123 group applications
- Comprising:
  - 378 full members
  - 360 associate members
  - 747 member applications in total
- Note: old Proto-Consortium list had 345 people

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and Technology Centre
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2201 AZ Noordwijk
The Netherlands
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F +31 (0)71 565 6040
www.esa.int

DESIGN DESCRIPTION

LISA Payload Description Document

Prepared by	**LISA Instrument Group**
Reference	**ESA-L3-EST-INST-DD-001**
Issue/Revision	**1.1**
Date of Issue	**December 4, 2017**
Status	**Issued**

European Space Agency
Agence spatiale européenne

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and Technology Centre
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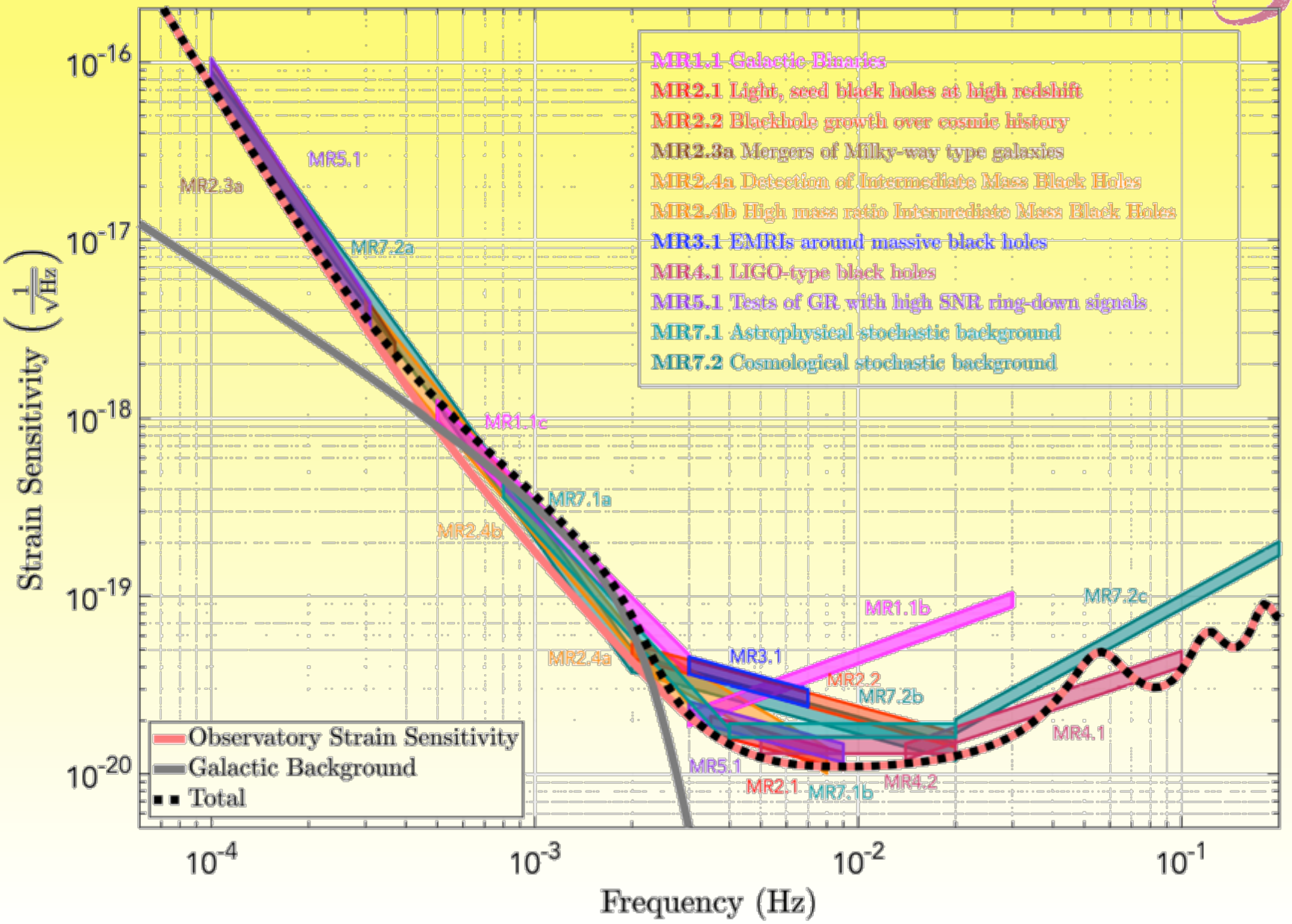
F +31 (0)71 565 6040
www.esa.int

LISA Science Requirements Document

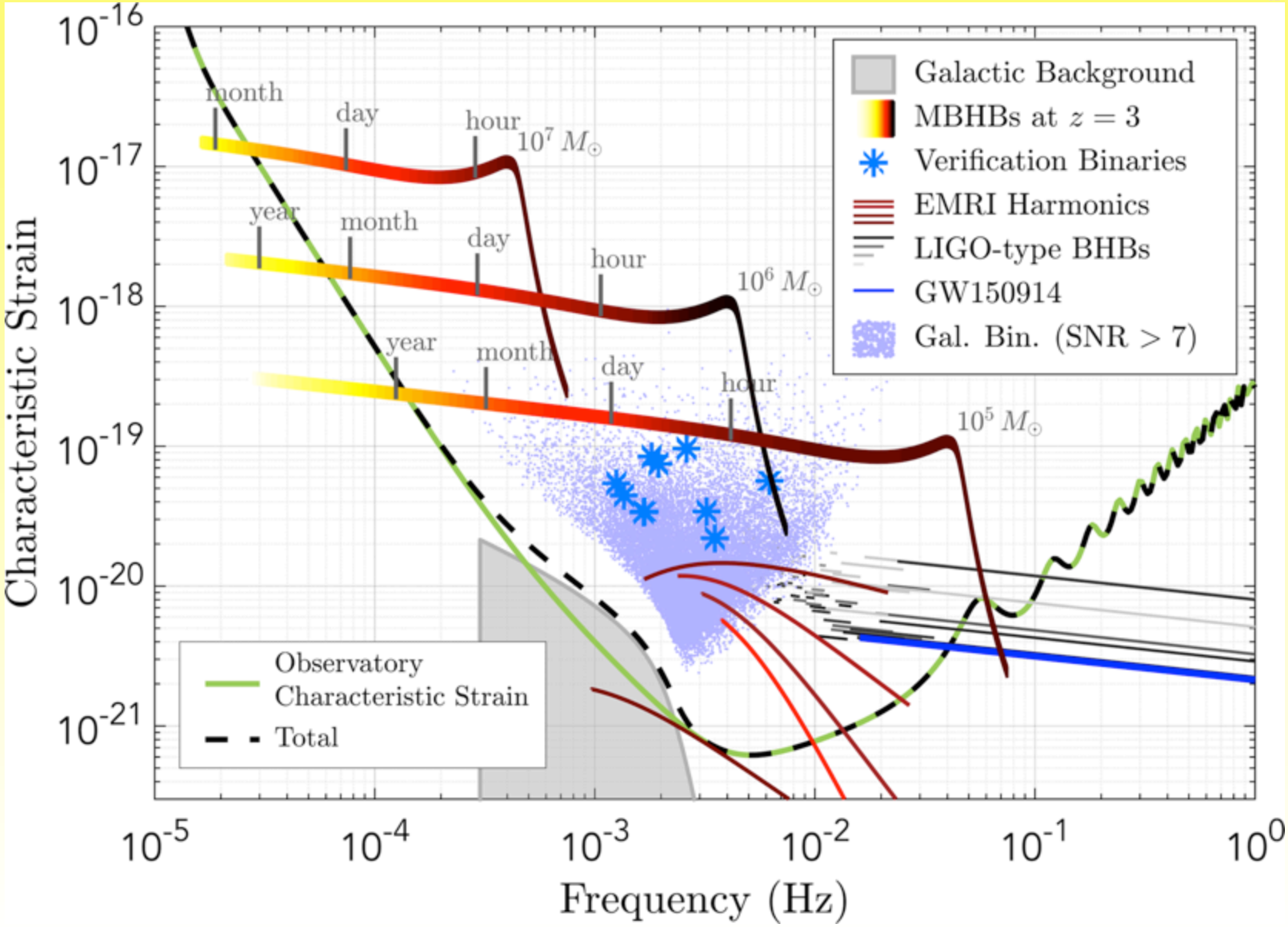
Prepared by	**LISA Science Study Team**
Reference	**ESA-L3-EST-SCI-RS-001**
Issue/Revision	**0.9**
Date of Issue	**19th April 2018**
Status	**Issued (None) ((None)) (None)**

European Space Agency
Agence spatiale européenne

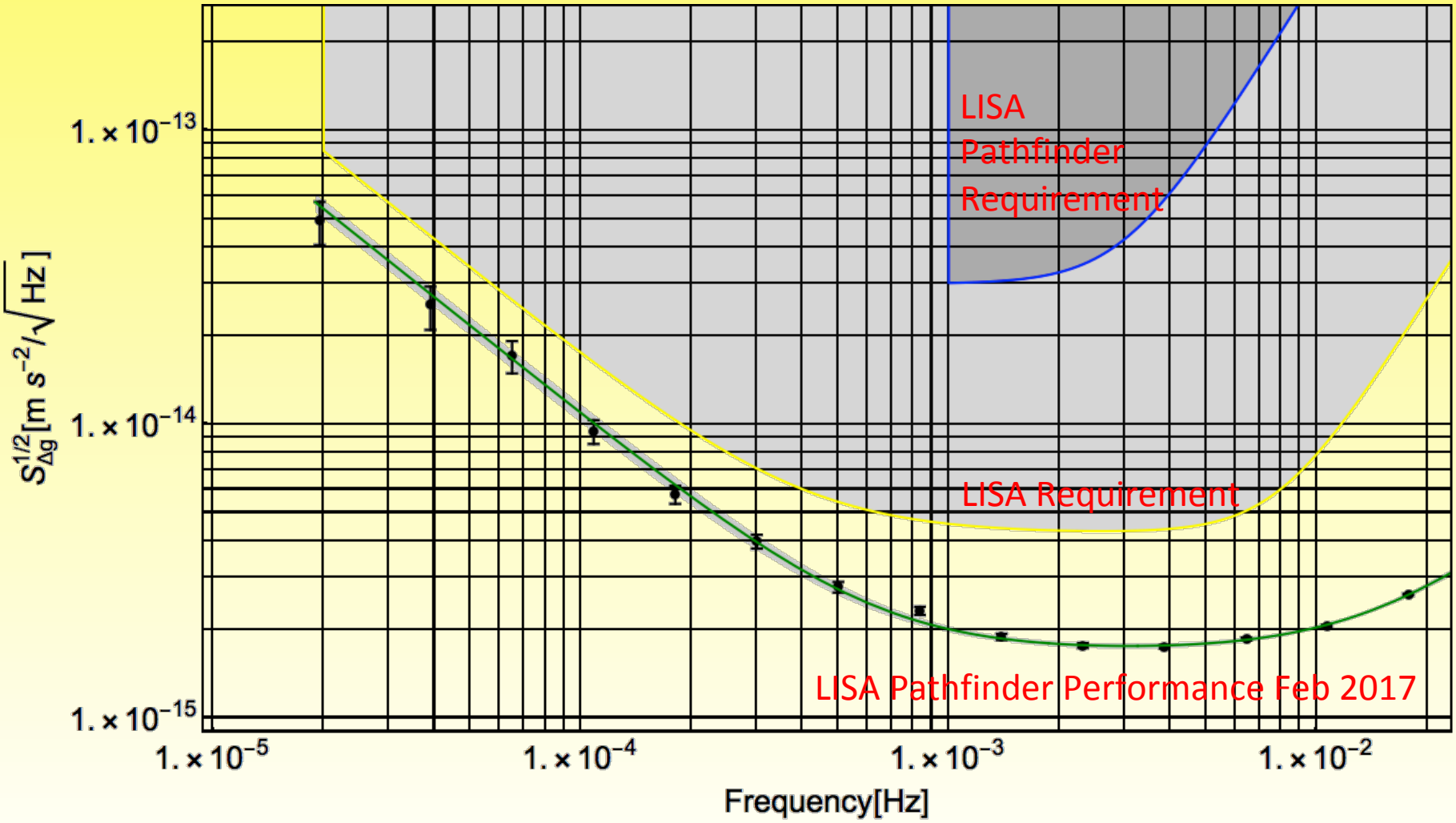
LISA Requirements



LISA Sources



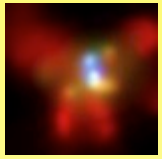
LISA Pathfinder shows: LISA Works!



Science by 2030

- Observatories
  - Ground
    - LHC, LSST, (EELT, TMT, GMT, OWL), SKA, ALMA, EHT
  - Space
    - JWST, EUCLID, Gaia, WFIRST, eROSITA, GRAVITY
  - Ground-based GW observatories
    - aLIGO, aVIRGO, KAGRA, ET
- Big science questions
  - Cosmic structure formation and Black Hole growth
  - Physics beyond Higgs, supersymmetry, extra dimensions, Phase transitions on TeV scale, cosmic strings, Dark Matter
  - Physics of Dark Energy, gravitation, new fields

LISA for Astrophysics, Cosmology, and Fundamental Physics



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

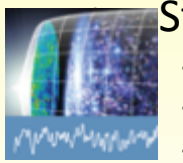
- When did the first Black Holes appear in pre-galactic halos and what is their mass and spin?
- How did Black Holes form, assemble and evolve from cosmic dawn to present time, due to accretion and mergers?
- What role did Black Holes play in re-ionisation, galaxy evolution and structure formation?
- 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 x 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?

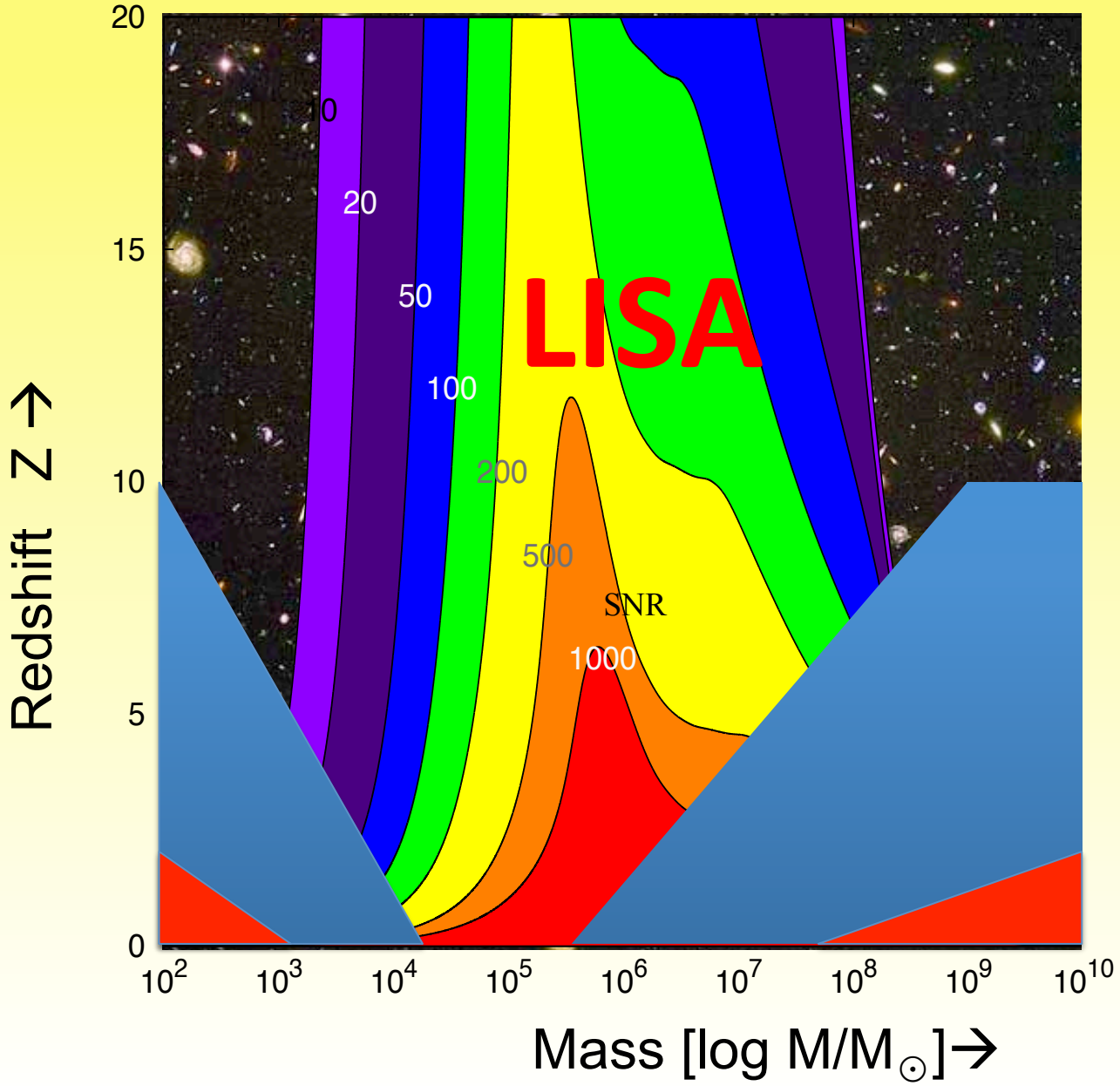


Stochastic Signals

- 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



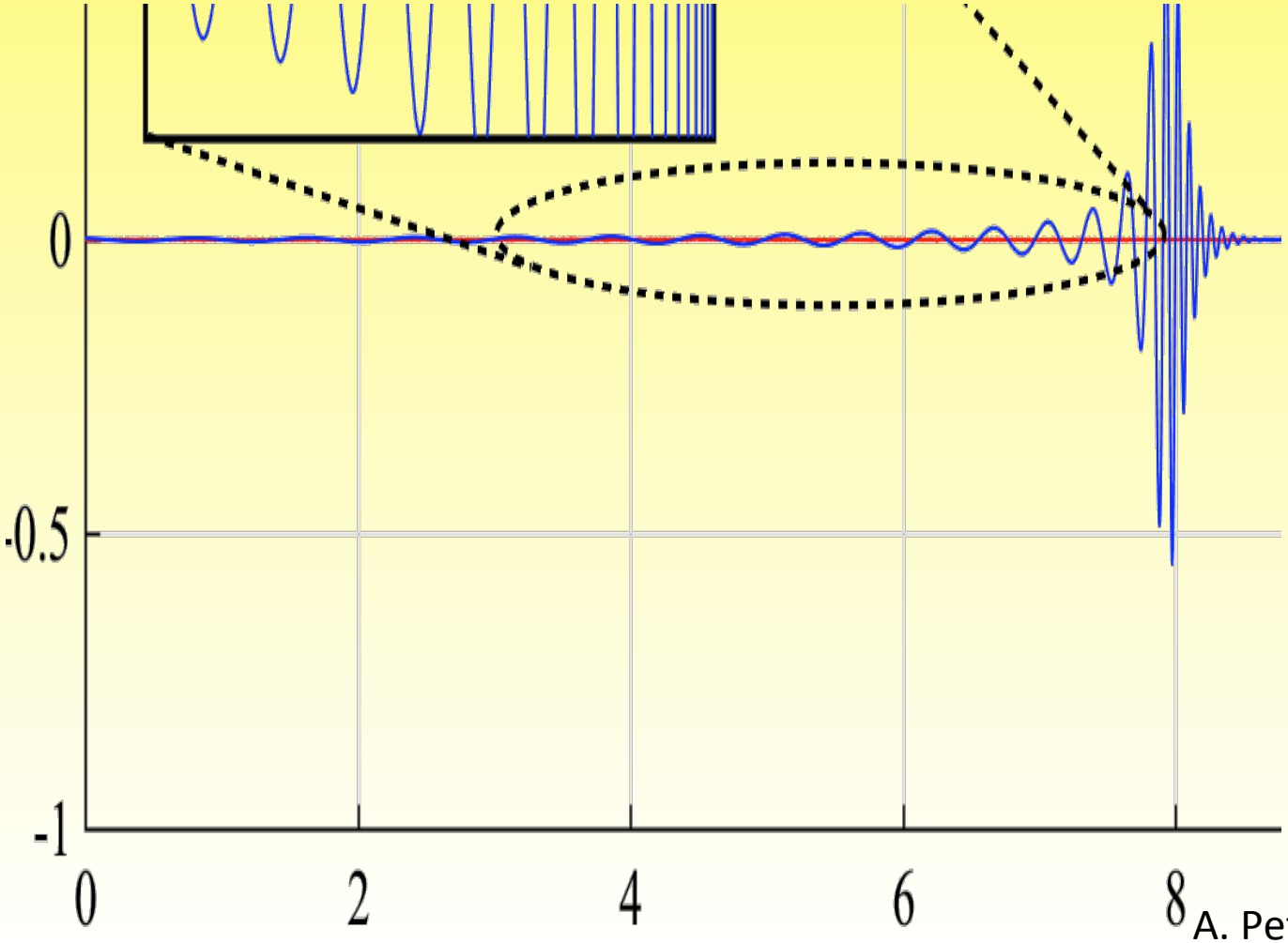
Black Hole Mergers far above Noise

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

A. Petiteau 2016

Black Hole Merger far above Noise

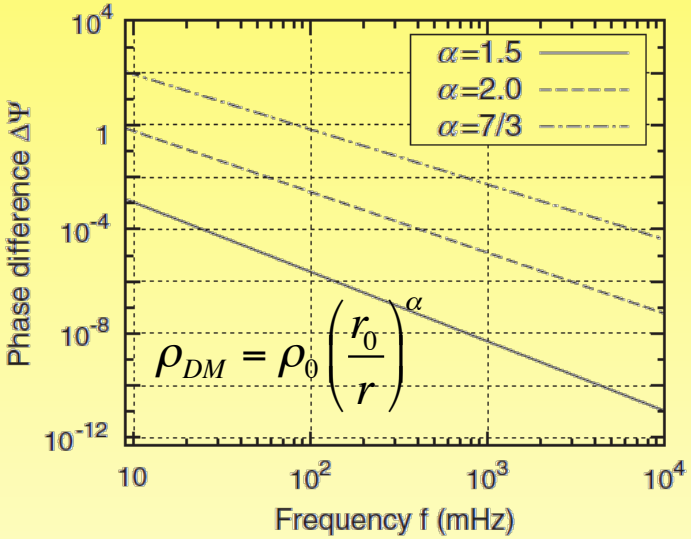
- $10^5\ M_\odot$ BH binary merger at z=5
- In Red: Pathfinder instrumental noise



A. Petiteau 2016

Dark Matter Probe

- Dark Matter spike around BH changes inspiral GW phase
- Sensitive even to Dark Matter interacting only gravitationally



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New Probe of Dark-Matter Properties: Gravitational Waves from an Intermediate-Mass Black Hole Embedded in a Dark-Matter Minispike

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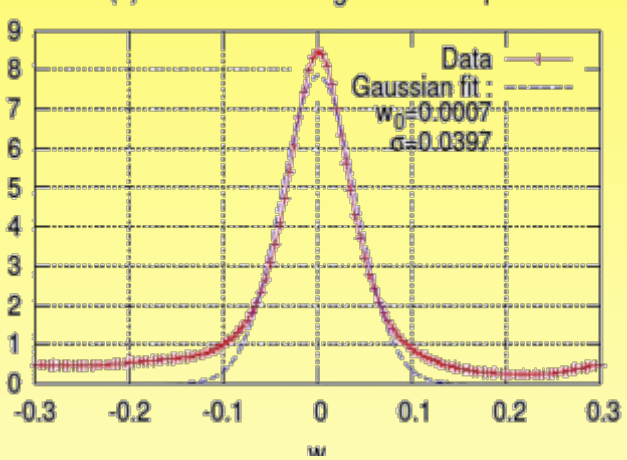
Cosmology with Standard Sirens

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

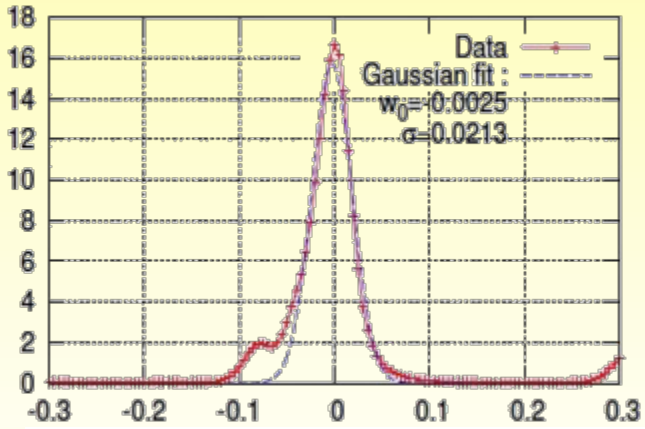
- EMRIs, *without* EM counterparts:
- Hubble const. H_0 to ±0.4% = ±0.3 km s^{-1} Mpc^{-1} after 20 EMRI detections: ~3 months LISA (MacLeod & Hogan, PRD, 2008; SDSS)
- Compare WMAP: ±1.2 km s^{-1} Mpc^{-1}.

- MBH mergers out to z = 3, *no* EM counterparts:
- Dark energy equation of state parameter w to ±2-4% in 3 years (Petiteau et al, ApJ, 2011; Millennium).
- Compare EUCLID: ±2%.

No identifications

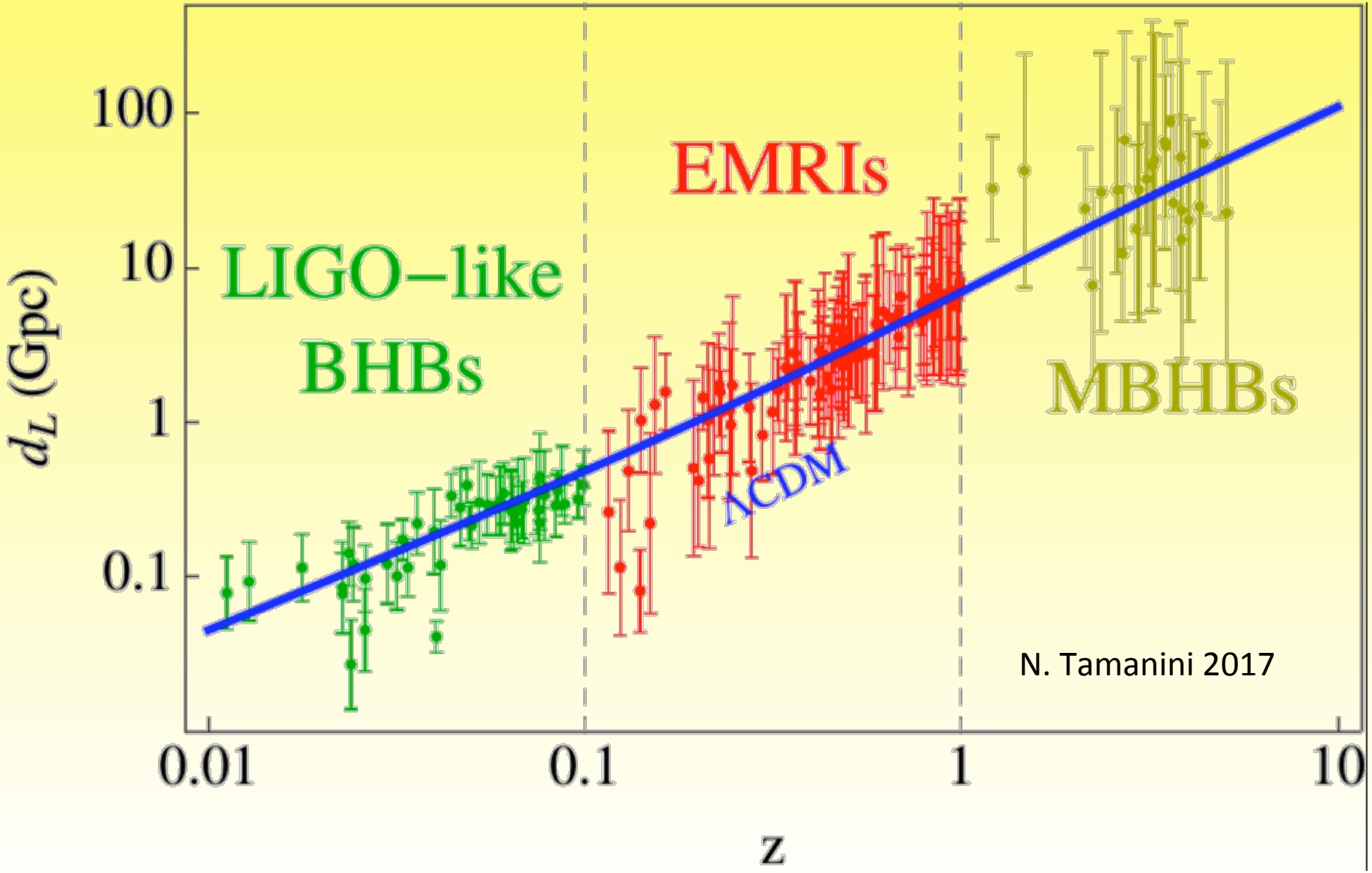


With identifications



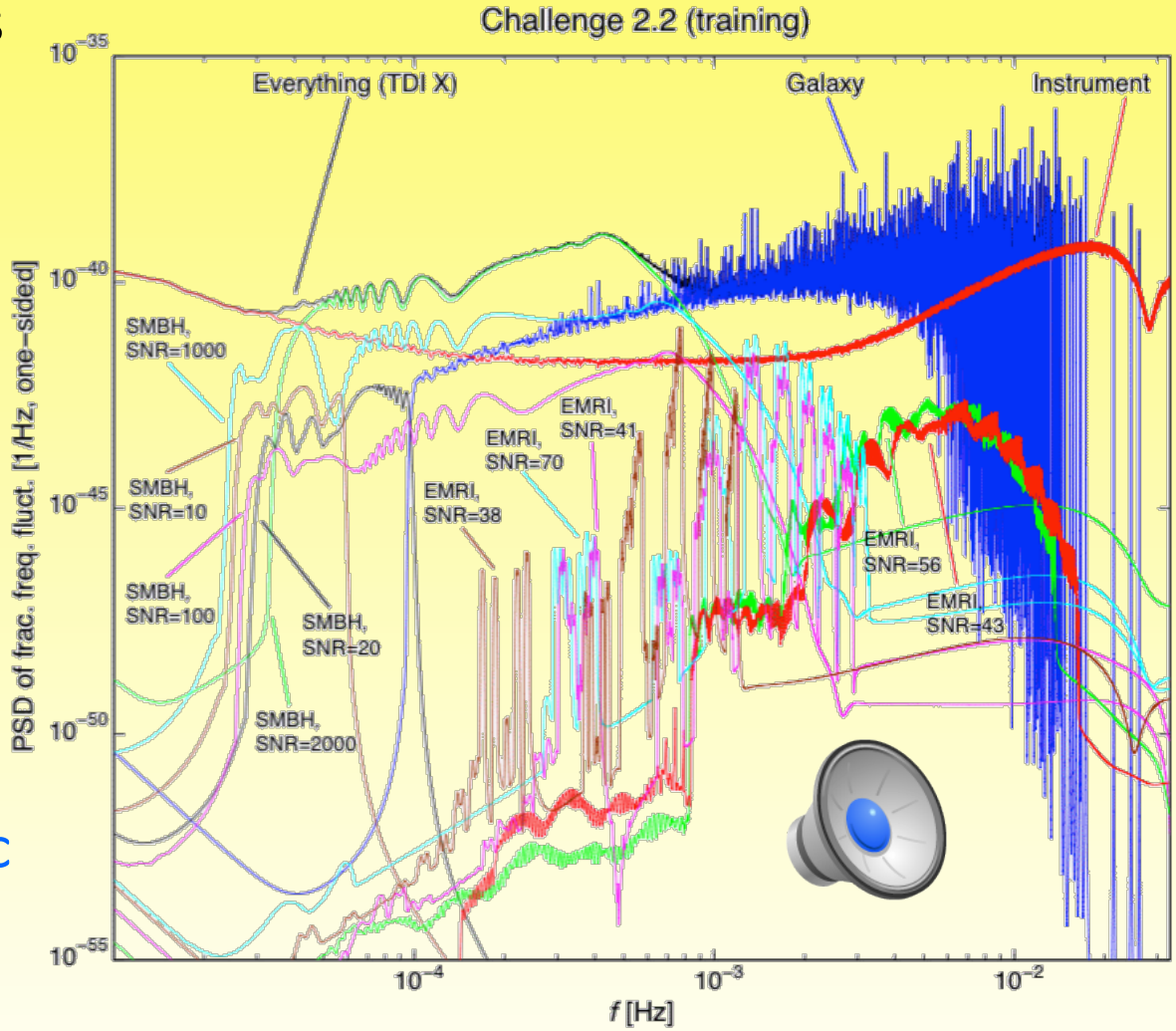
Dark Energy equation-of-state parameter w

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



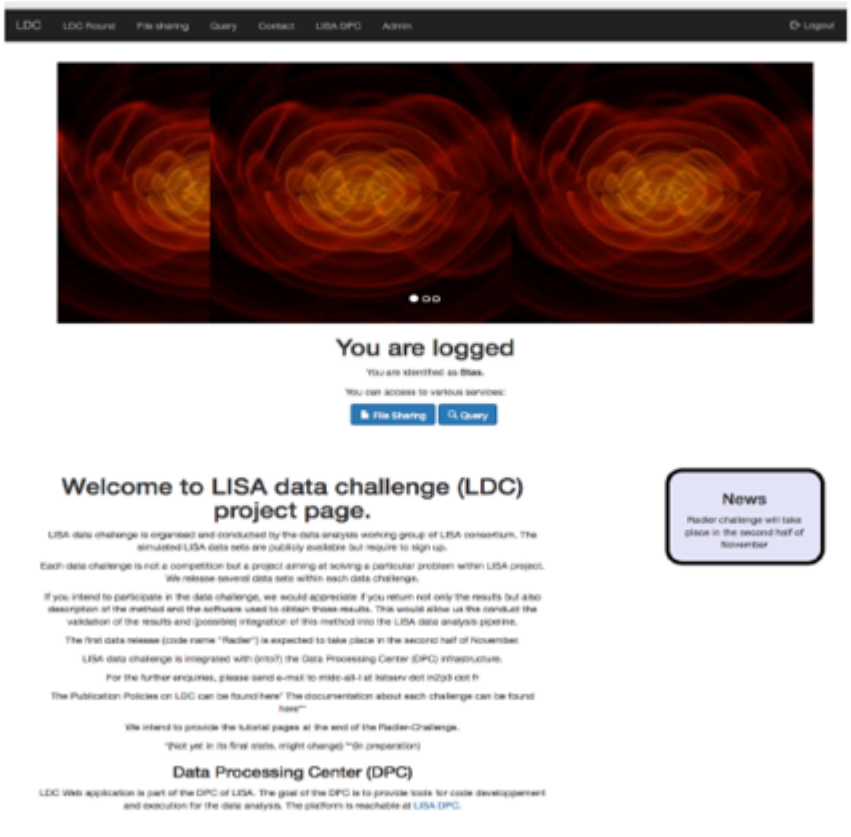
- Effective data analysis algorithms are needed!

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 is open for everyone to sign up for the challenge and download the simulated data set.

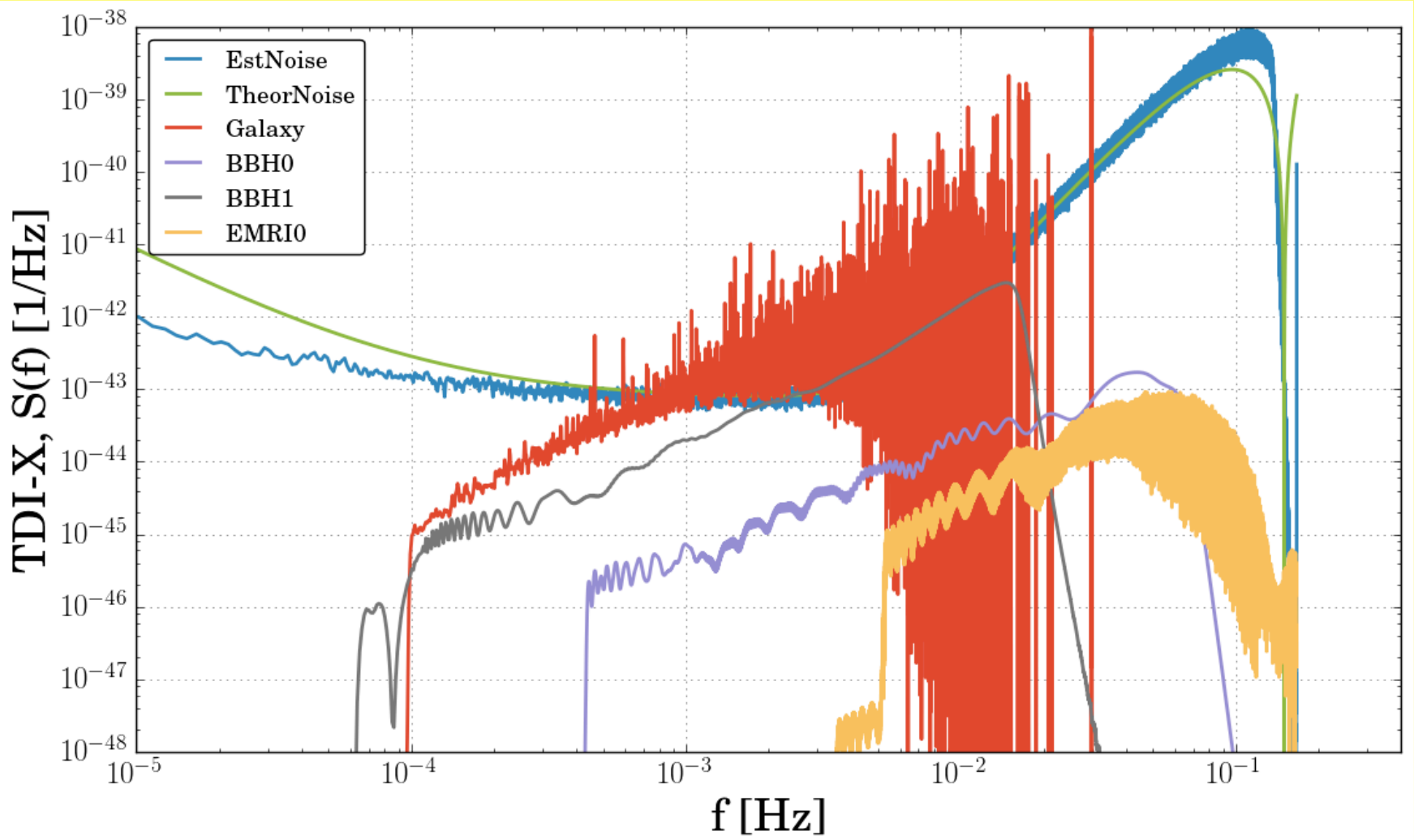
LDC webpage

- The project is hosted under git-lab https://gitlab.in2p3.fr/stas/MLDC (sign up is required)
- There are bi-weekly teleconferences. The web-page is open (requires registration). https://lisa-ldc.lal.in2p3.fr/home



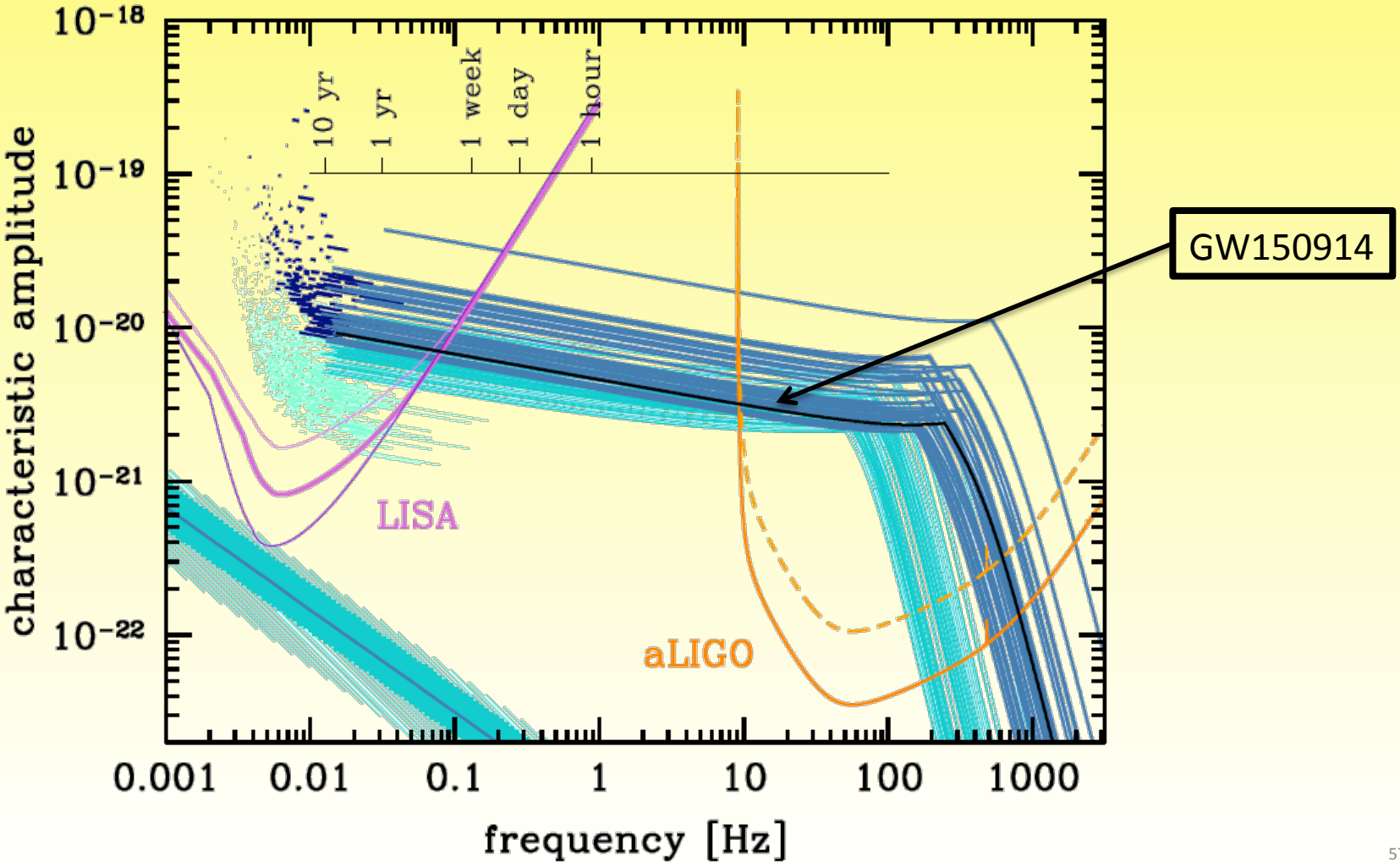
First Data Release

- Several data sets:



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
- Nominally Launch of L2 in 2028
- Nominally Launch of L3 in 2034
- Launch LISA and Athena together?