



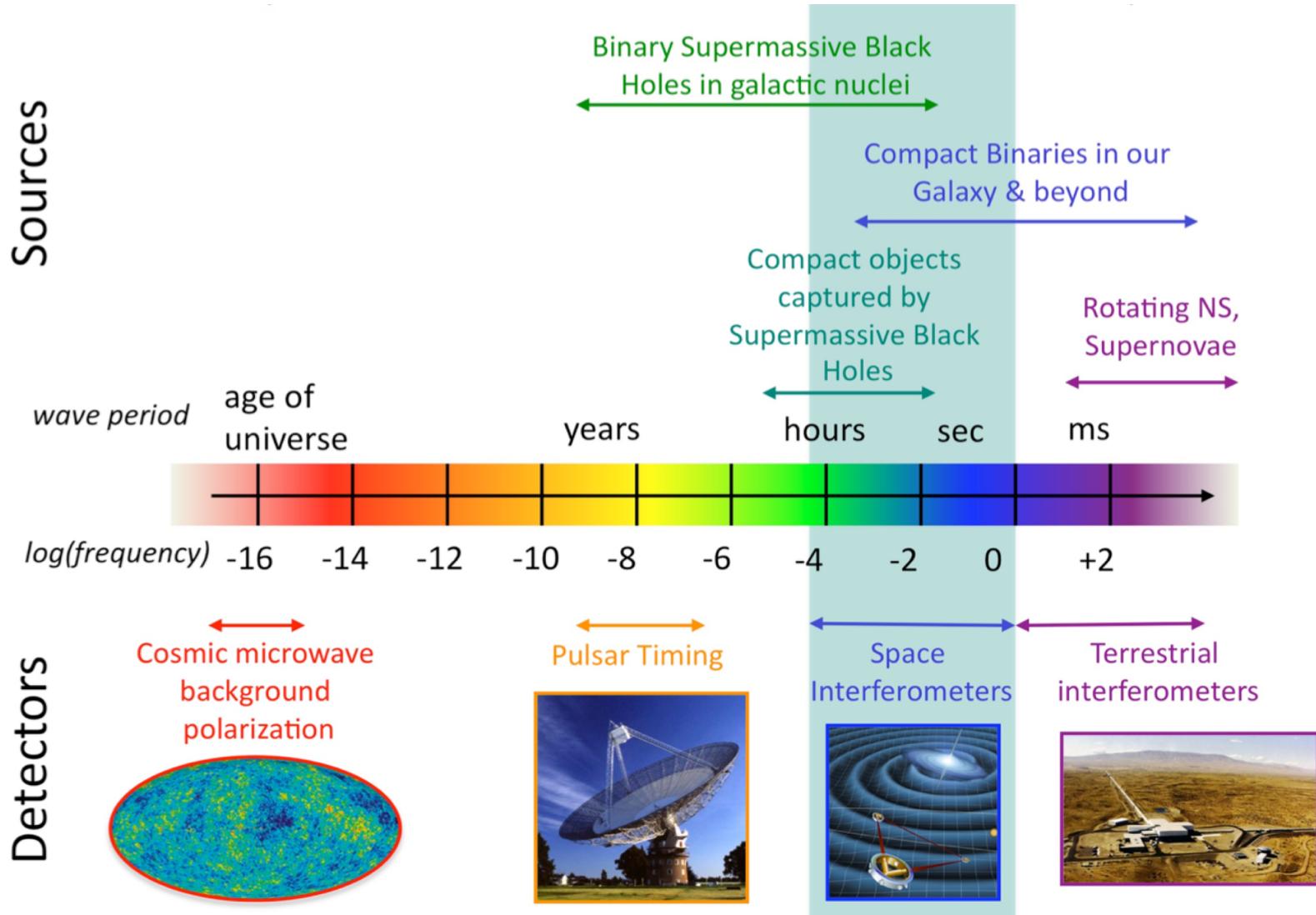
From LISA Pathfinder to LISA a gravitational waves space-based observatory

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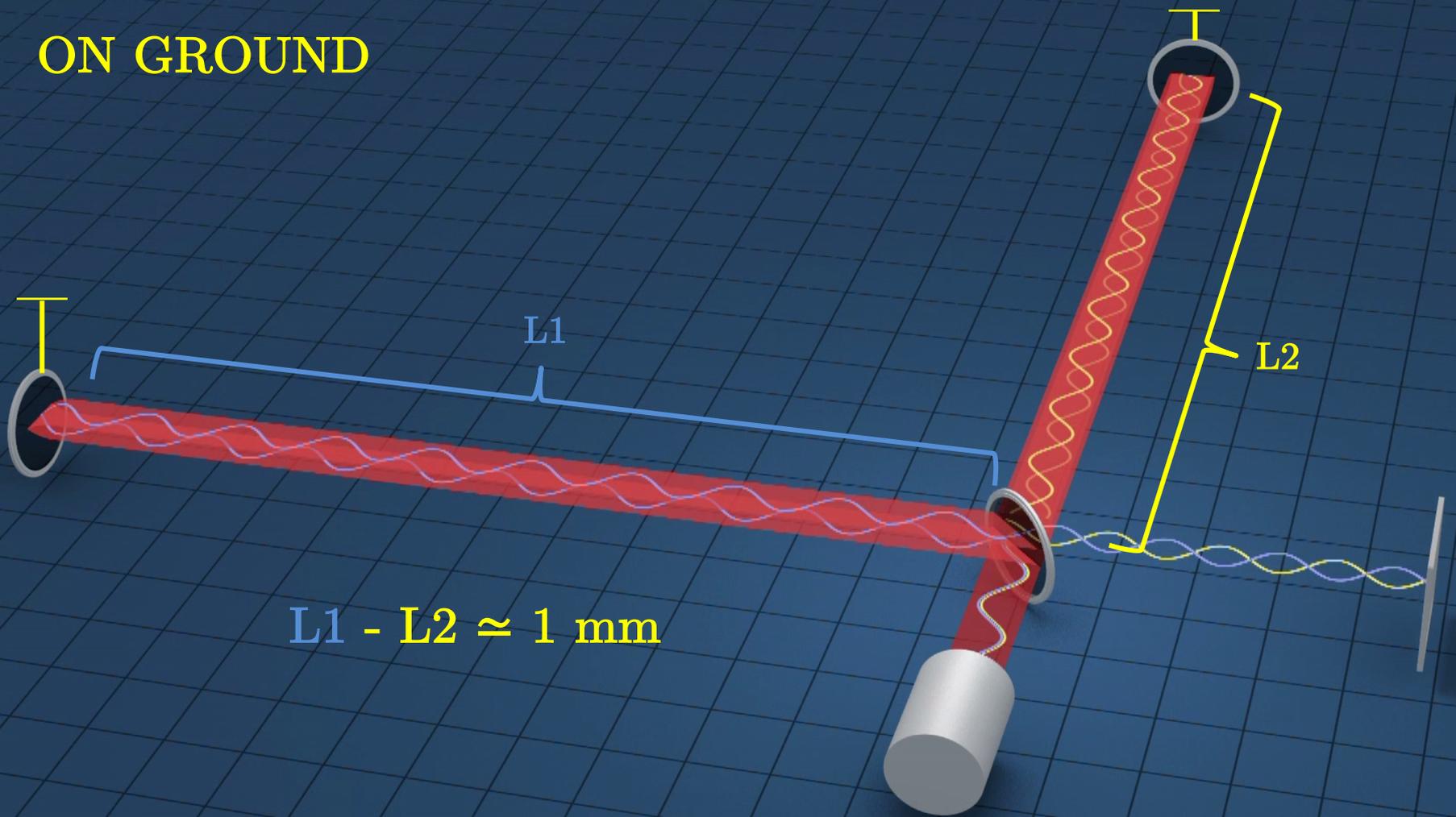


The Gravitational waves spectrum



Freely-falling suspended mirrors and “equal” arms

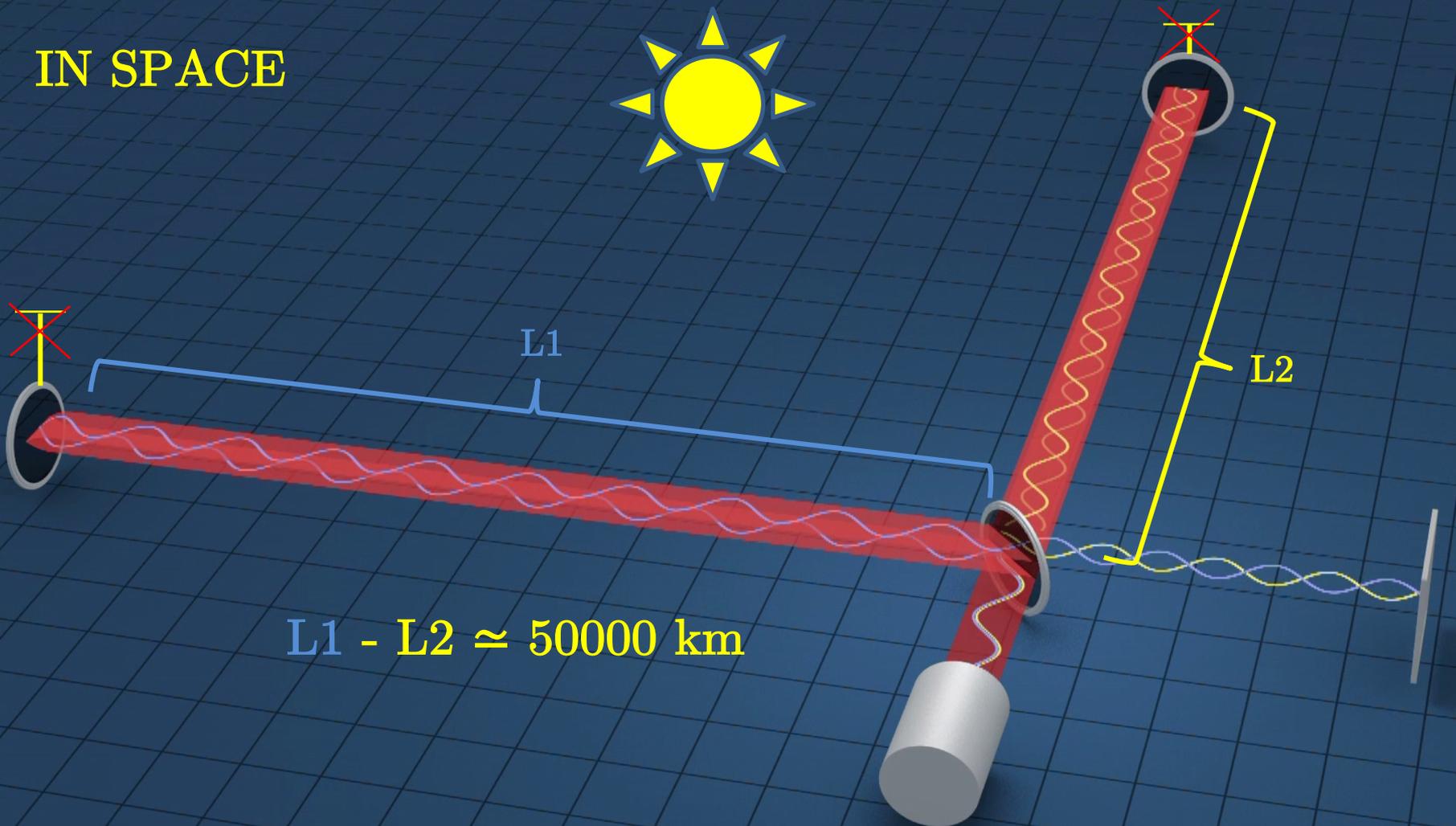
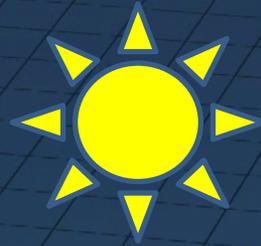
ON GROUND



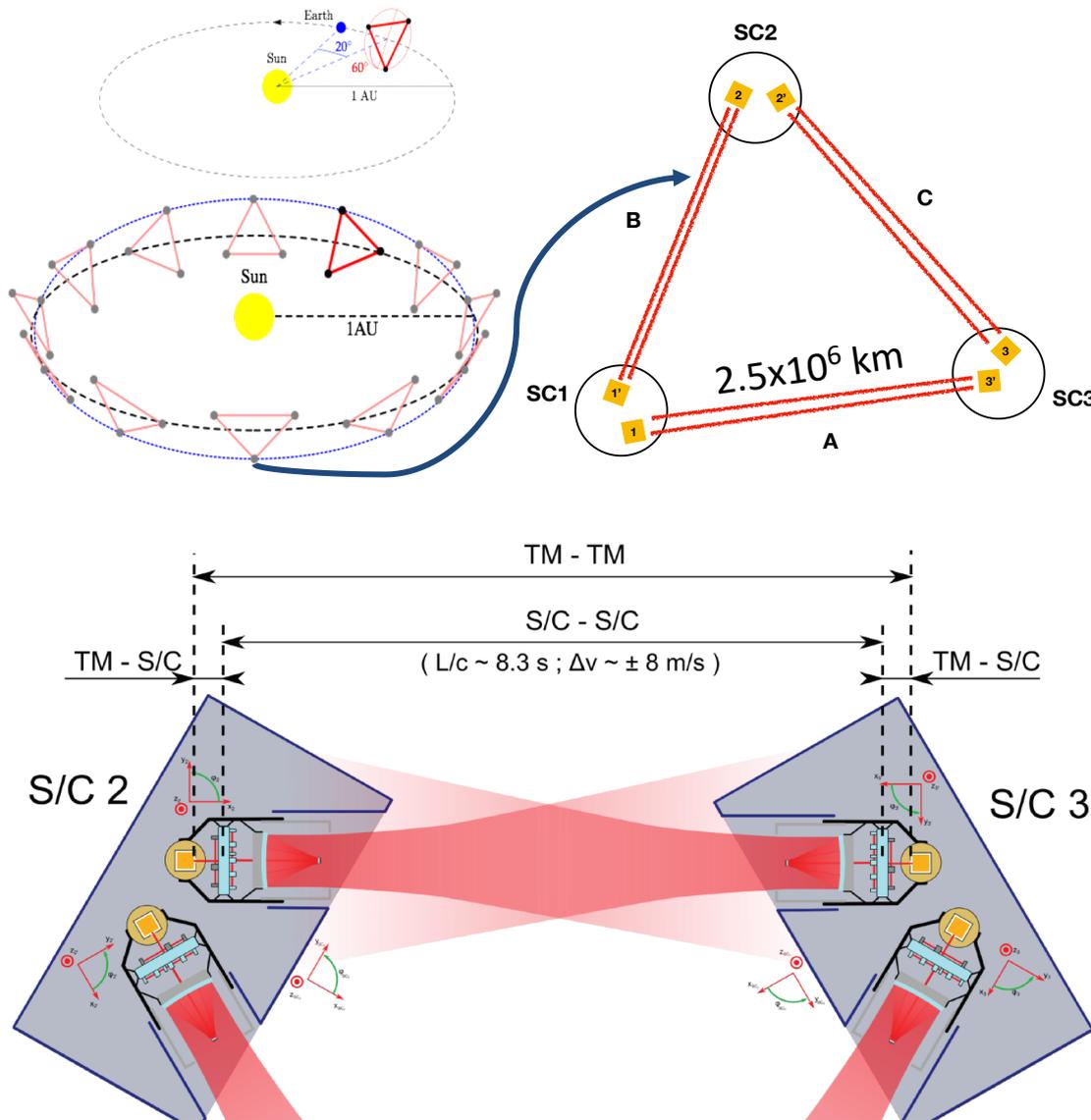
$$L_1 - L_2 \approx 1 \text{ mm}$$

“Orbiting” mirrors and no pendulum!

IN SPACE



LISA: the Laser Interferometer Space Antenna

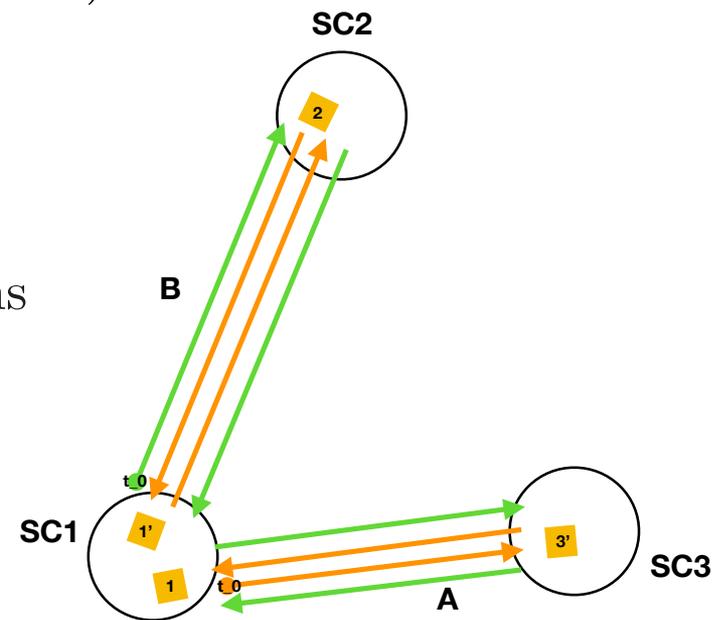


- Heliocentric orbit, Earth-trailing
- $\sim 10^6$ km IFO, Drag-free SC
- MOSA (Moving Optical Sub-Assembly): Telescope, Optical bench, Gravity Reference Sensor
- 2 W 1064 nm lasers
- 30 cm telescope
- transponder instead of reflection (100 pW at far SC)
- Split interferometry

LISA suppresses laser frequency noise by TDI

Time delay Interferometry (TDI 1.0, 2.0)

- combines time delayed observable to synthesize equal arm pathlength (work by Tinto, Armstrong, Estabrook et al...) at 1 m (3 ns) level
- Michelson combinations + Sagnac + ...
- mixes signals and introduces correlations



LISA metrology

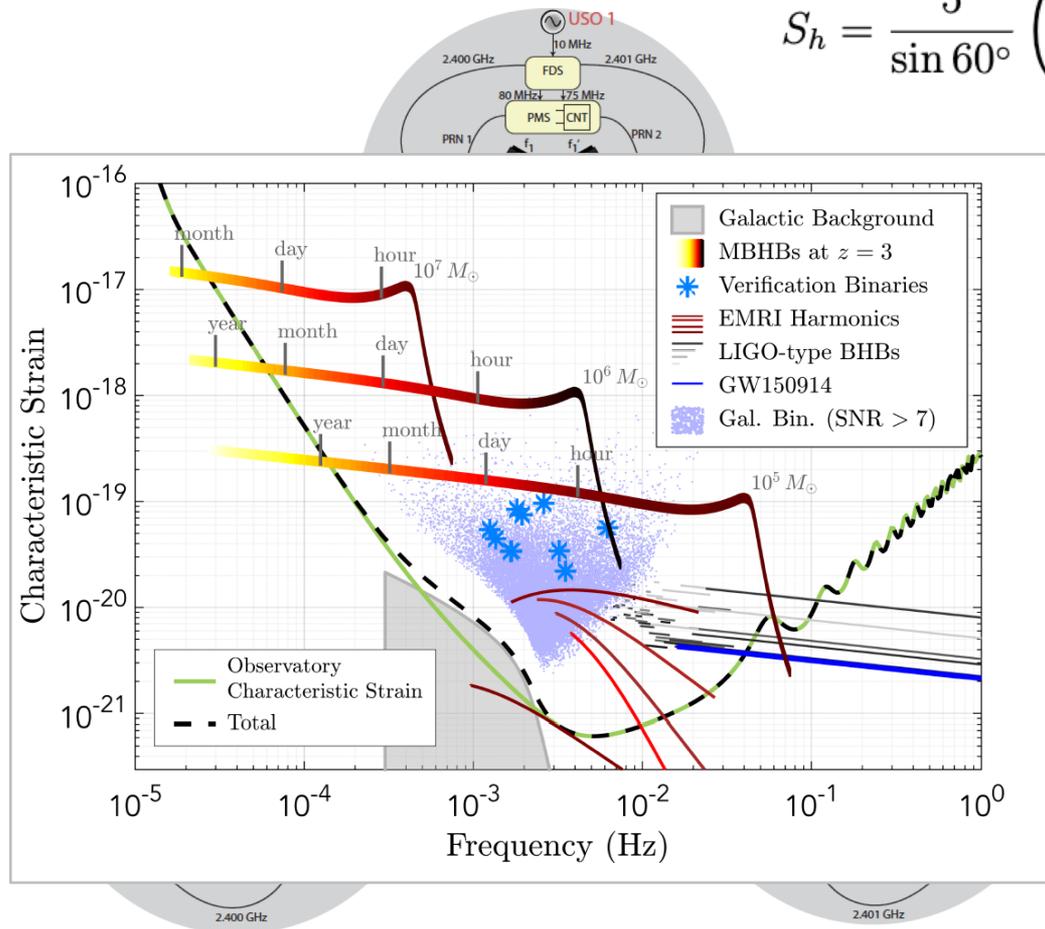
Noise is composed by “IFO noise + acceleration noise”

$$S_h = \frac{5}{\sin 60^\circ} \left(\frac{T_{arm}}{L} \right)^2 \left(S_{\delta\nu} (\Delta L)^2 + S_{IFO} + \frac{4}{(2\pi f)^2} S_{acc} \right)$$

laser freq
noise

displacement
noise

acceleration
noise



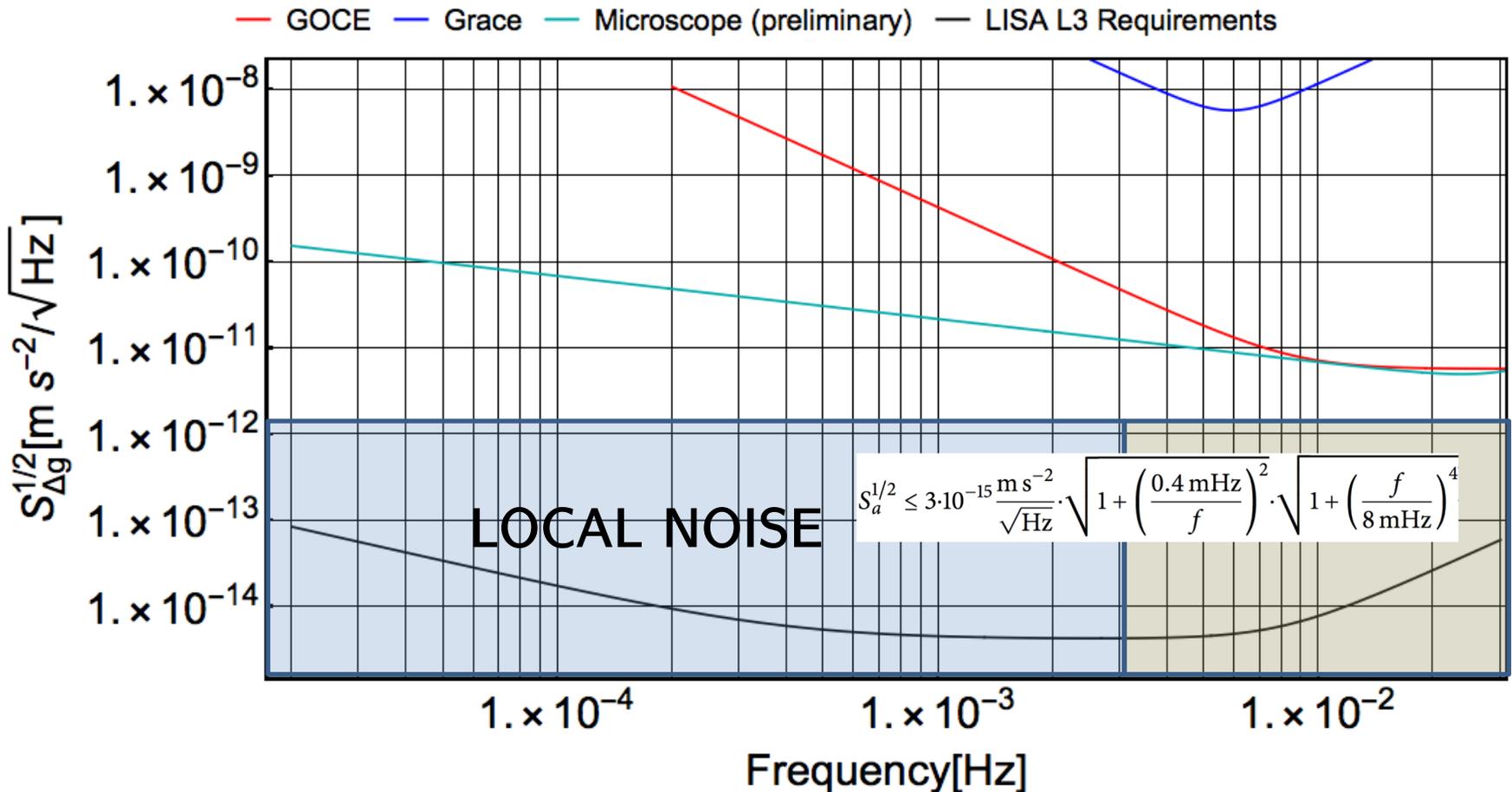
Requirements

- Displacement noise $\sim 10 \text{ pm}/\sqrt{\text{Hz}}$
- Free-falling TM $\sim 3 \text{ fm}/\text{s}^2/\sqrt{\text{Hz}}$

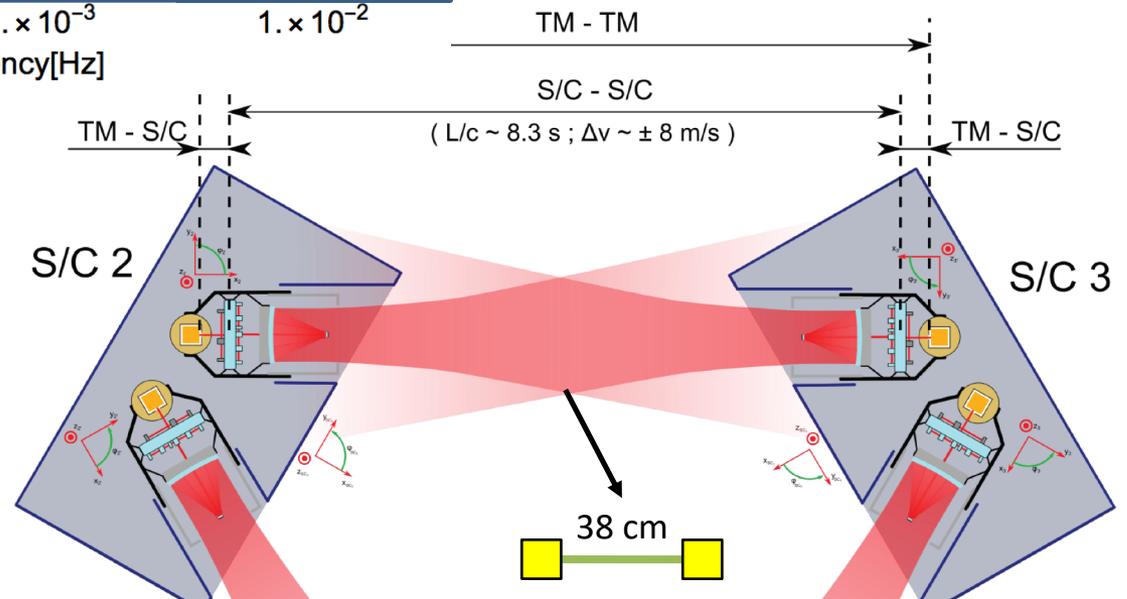
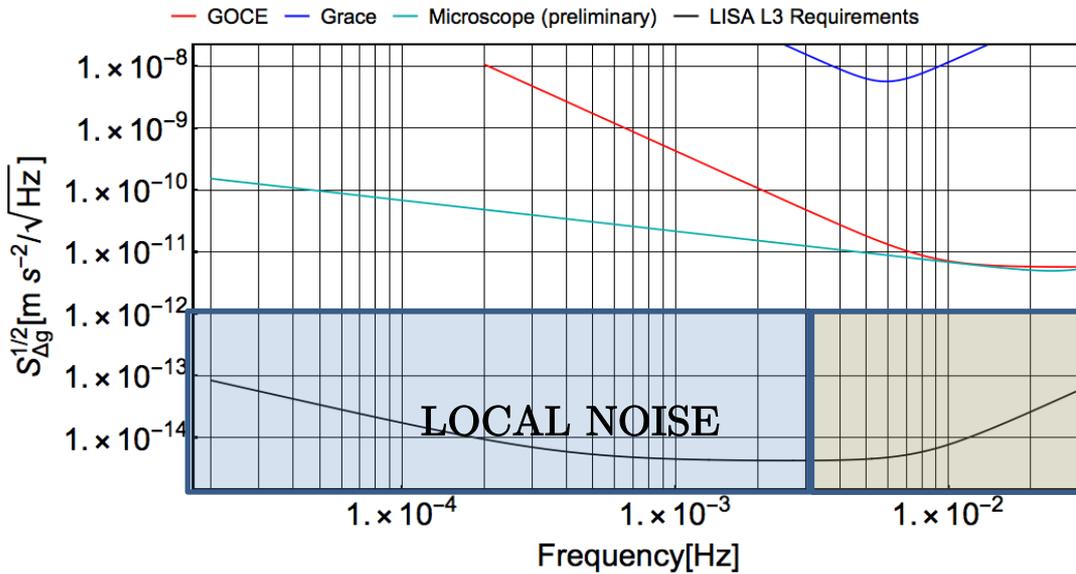
But

- Relative velocity of 10 m/s
- MHz doppler variation
- arm breathing of 1 deg per year

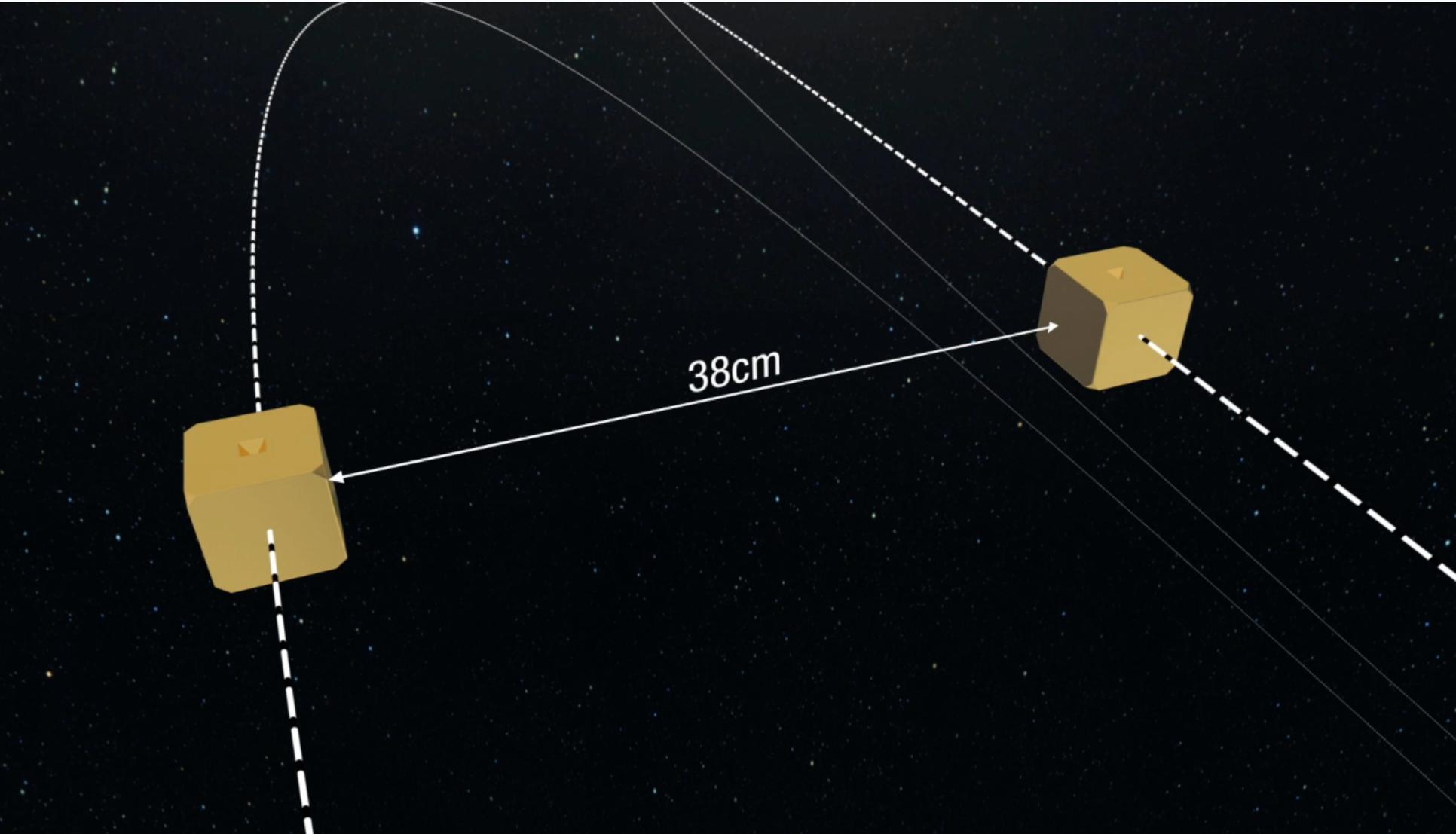
Force noise in LISA is in the local spacecraft



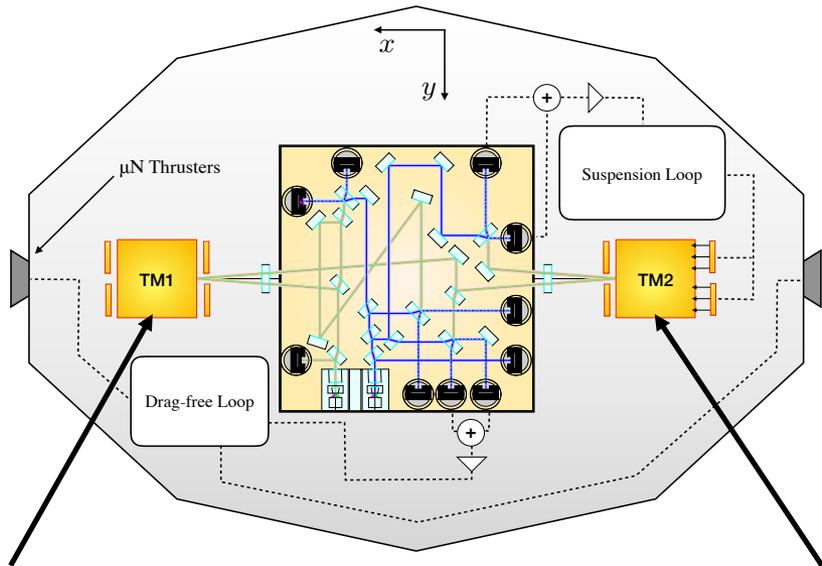
Force noise in LISA is in the local spacecraft



LISA Pathfinder: the LISA technology demonstrator



LISA Pathfinder working principle



- Drag-free satellite
- Slow capacitive controller via audio-frequencies AC voltages
- Picometre interferometry

$$\ddot{x}_1(t) = f_{sc} - \omega_1^2 x_1 + g_1$$

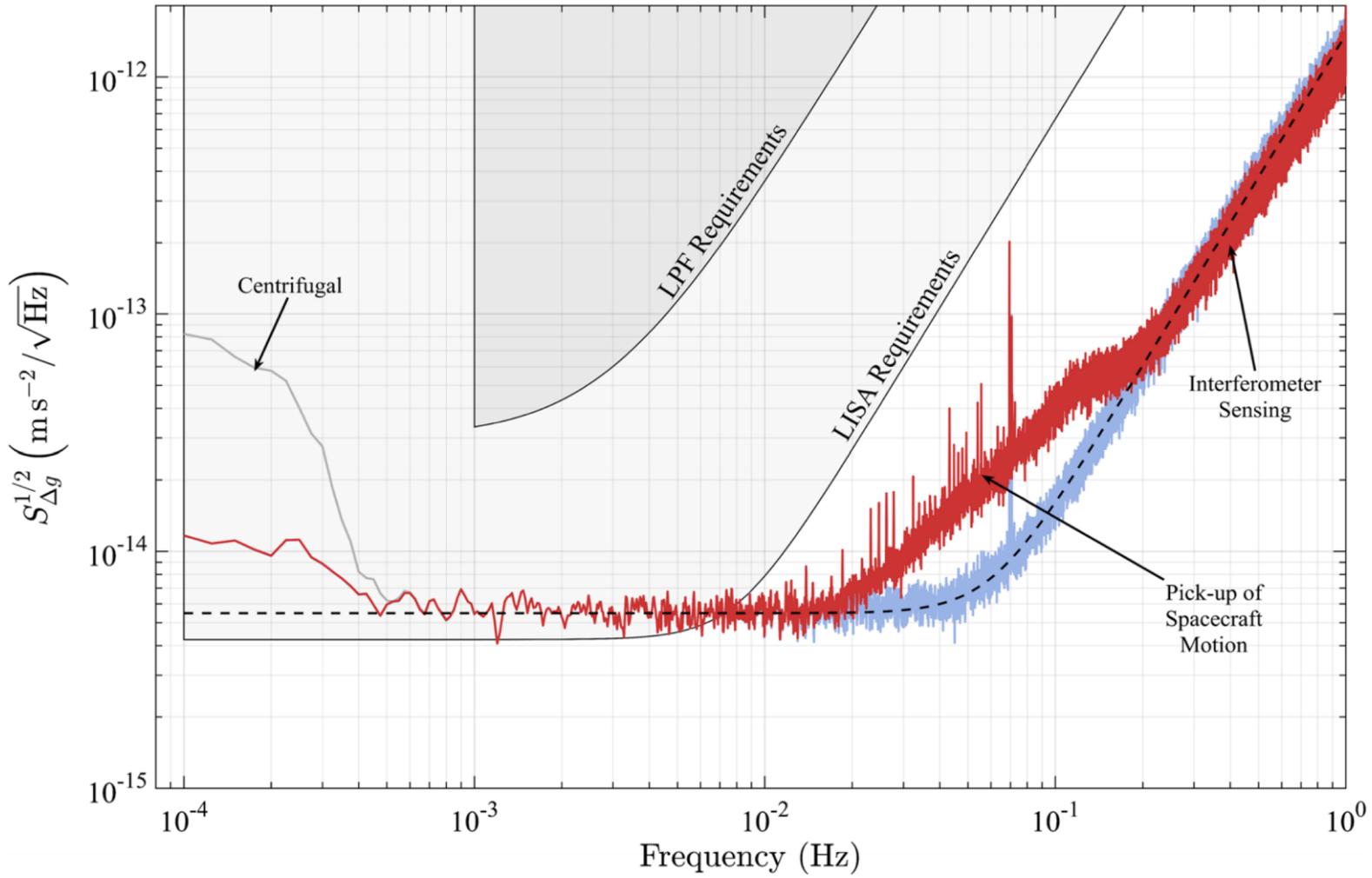
$$\ddot{x}_2(t) = f_{sc} + f_{2,cmd} - \omega_2^2 x_2 + g_2$$

$$\Delta g_x[t] \equiv \Delta \ddot{x}[t] + \lambda_1 f_{x_1}[t] - \lambda_2 f_{x_2}[t] - C_1 \dot{f}_{x_1}[t] + C_2 \dot{f}_{x_2}[t] + \omega_2^2 \Delta x[t] + \Delta \omega_{12}^2 x_1[t],$$

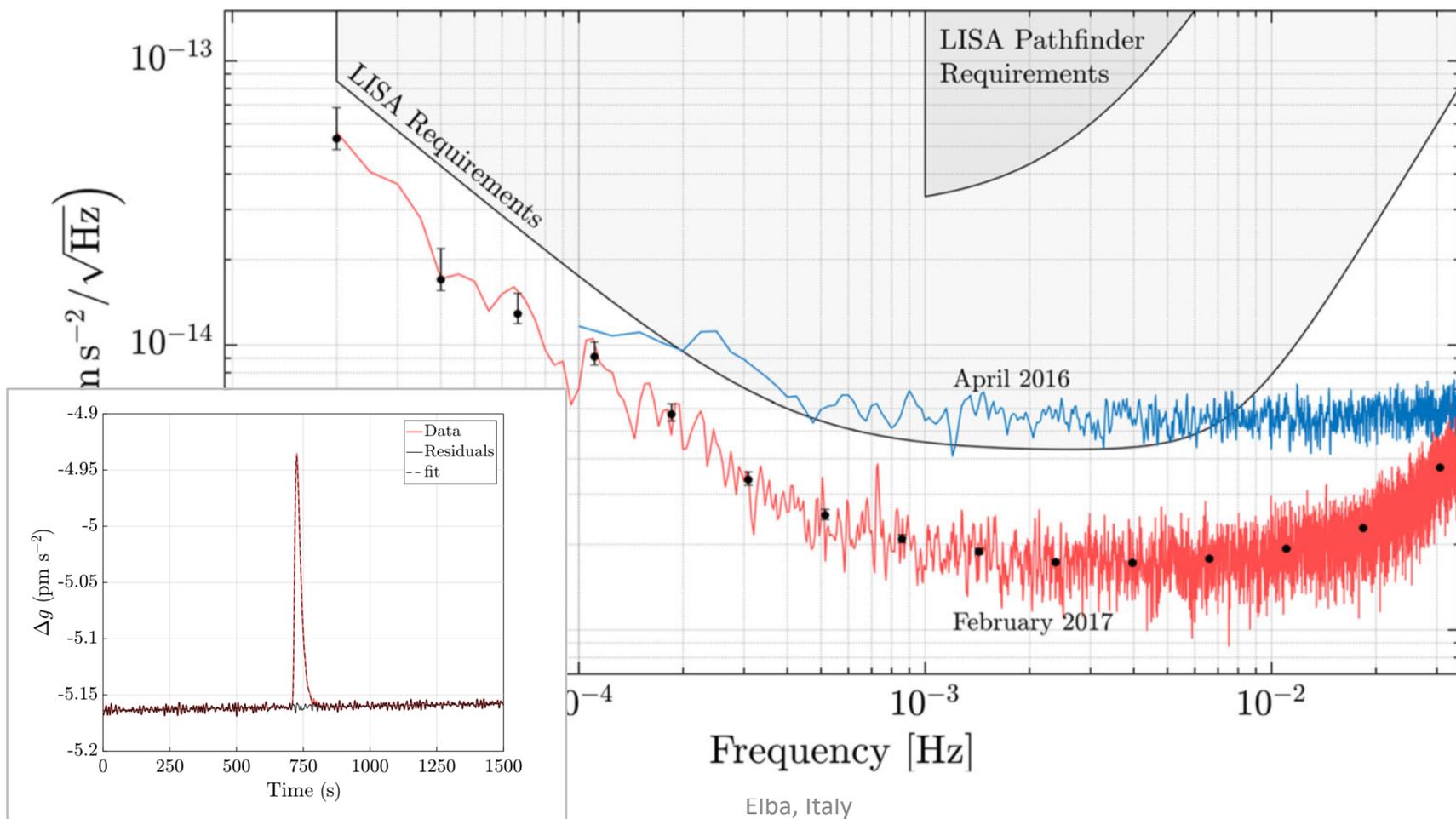
Need to be calibrated



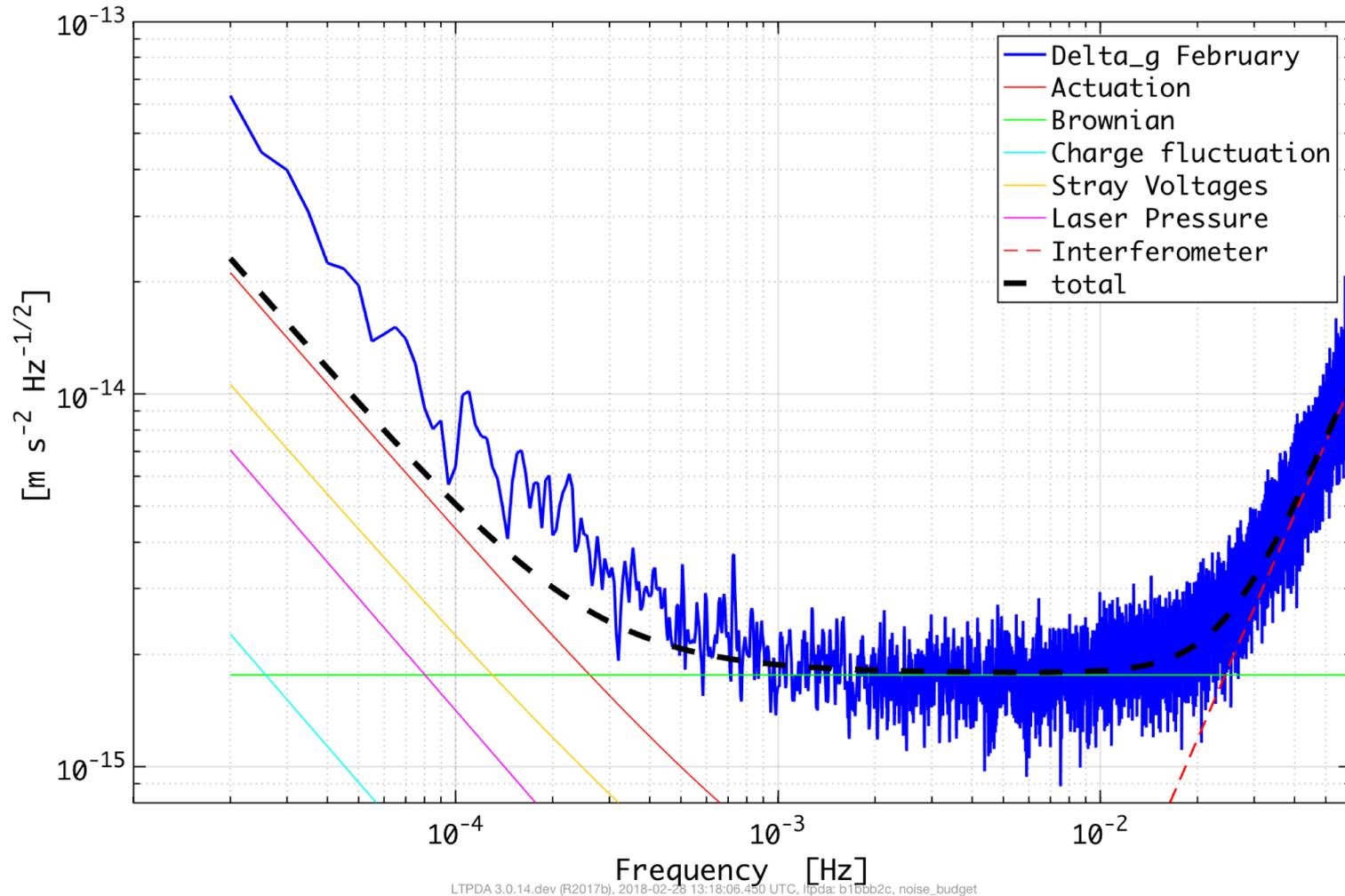
Sub-Femto-g Free Fall for Space-Based Gravitational Wave Observatories: LISA Pathfinder Results



Beyond the Required LISA Free-Fall Performance: New LISA Pathfinder Results down to 20 μHz



Modeled forces do not fully explain noise

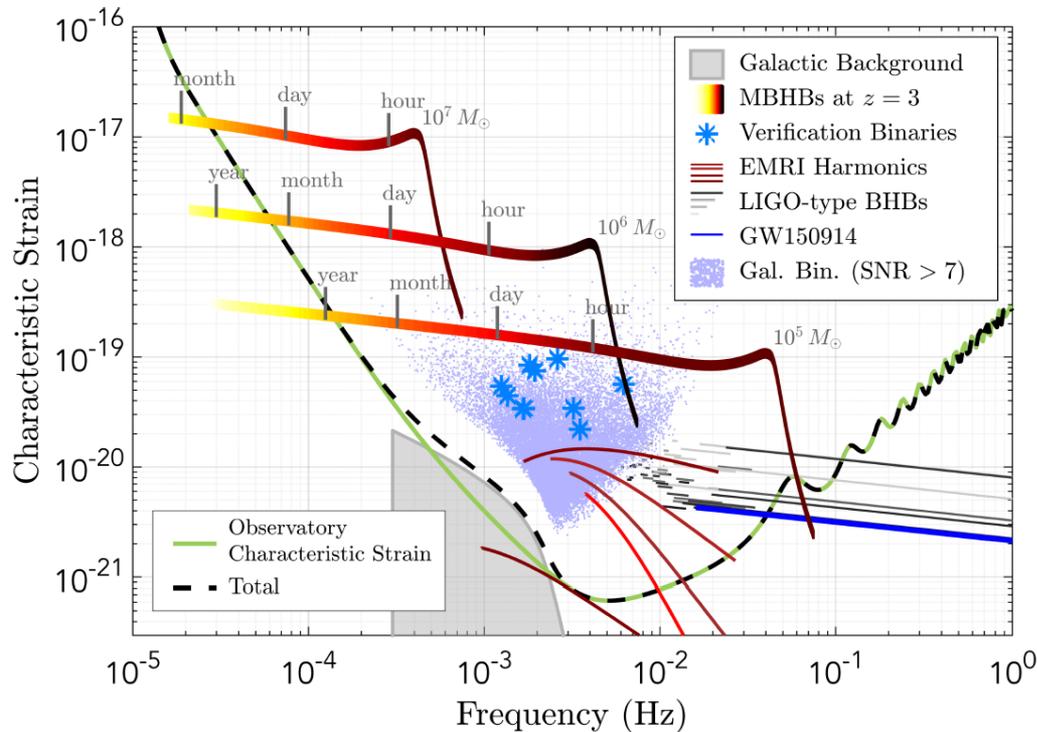


From LPF to LISA

- In LISA all the TMs will be drag-free along their x-axis.
- Force gradients and Tilt-To-Length (TTL) need to be calibrated.
- Inertial forces in LISA could enter the signal through actuation crosstalk
- Force glitches need to be understood both as instrumental origin that for discrimination techniques
- TDI mixes many signals and introduces correlations that makes even instrument noise characterization non trivial



LISA landscape in the mid '30s



Expected sources

- $\sim 10 \div 10^2$ SMBHBs
- $\sim 1 \div 10^3$ EMRIs
- $\sim 10^5$ resolved galaxy binaries
- $\sim 10^6$ of unresolved
- LIGO/Virgo sources
- Discovery potentials
- Global fit in a huge high dimensional space, together with instrumental noise and GW stochastic foreground

LISA mission status

Timeline



October 2013:	Selection of "The Gravitational Universe" as science theme for the 3 rd ESA flagship mission (L3)
October 2016:	Call for mission proposals for L3
June 2017:	Selection of LISA as L3 with an anticipated 2034 launch date
May 2018:	Phase A Kick-Off
2018-2020:	Mission Phase A
<Mid 2020:	Formulation Review (end Phase A)
>2020:	Mission Phase B1
<2024:	Mission Adoption
>Adoption:	Mission Implementation (Phase B2/C/D)
<2034:	Launch
>Launch:	6.5 years operations (+6 years potential extension)

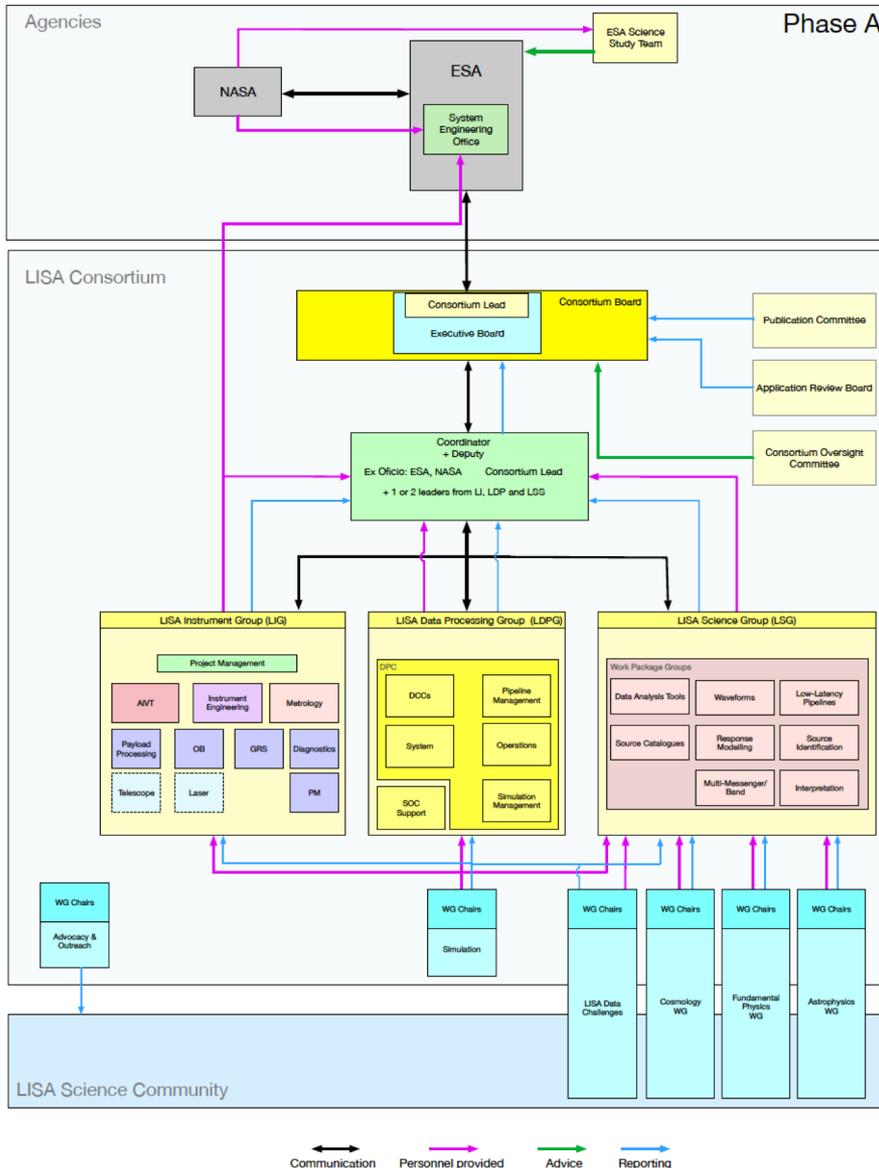
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Martin Gehler | ESA-LISA-EST-MIS-HO-016 | ESTEC | 29/04/2019 | Slide 3



European Space Agency

The LISA Consortium



Membership status

- We have received ~200 applications
- 199 external group applications have been board approved
- Currently have 1122 members
 - 498 full members
 - FTE = 196
 - median FTE = 0.3
 - 624 associate members



LISA Instrument Group	237 (33)
LISA Data Processing Group	78 (22)
LISA Science Group	260 (41)
Diversity & Inclusion Committee	14 (7)
Publication Committee	15
Astrophysics WG	387
Cosmology WG	258
Fundamental Physics WG	286
Waveform WG	153
Simulation WG	70
LISA Data Challenges WG	179
Advocacy & Outreach WG	46
Measurement Science WG	5

Join the LISA Consortium!

<https://signup.lisamission.org/>

The screenshot shows the LISA Consortium website. At the top left is the LISA logo with the tagline "We will observe gravitational waves in space". To the right is a search bar. Below the logo is a navigation menu with five items: "LISA MISSION", "LISA PATHFINDER", "GRAVITATIONAL WAVE ASTRONOMY", "CONTEXT 2030", and "CONSORTIUM". The "CONSORTIUM" item is highlighted. Below the navigation menu is a breadcrumb trail: "Home / Consortium / Join consortium". On the left side, there is a vertical menu with five items: "Consortium Group list", "Consortium User Guide Link", "Consortium Code of Conduct", "Consortium News", and "Join the community!". To the right of this menu are five social media sharing buttons: "tweet", "share" (Facebook), "share" (Google+), "share" (LinkedIn), "pin it" (Pinterest), and "share" (Reddit). Below these buttons is a grey banner with a right-pointing arrow and the text "The LISA community welcomes all scientists who wish to contribute." Below the banner is the heading "Consortium membership for scientists" and the text "If you are a scientist and wish to contribute to the LISA mission, use this **scientist registration form**."

