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

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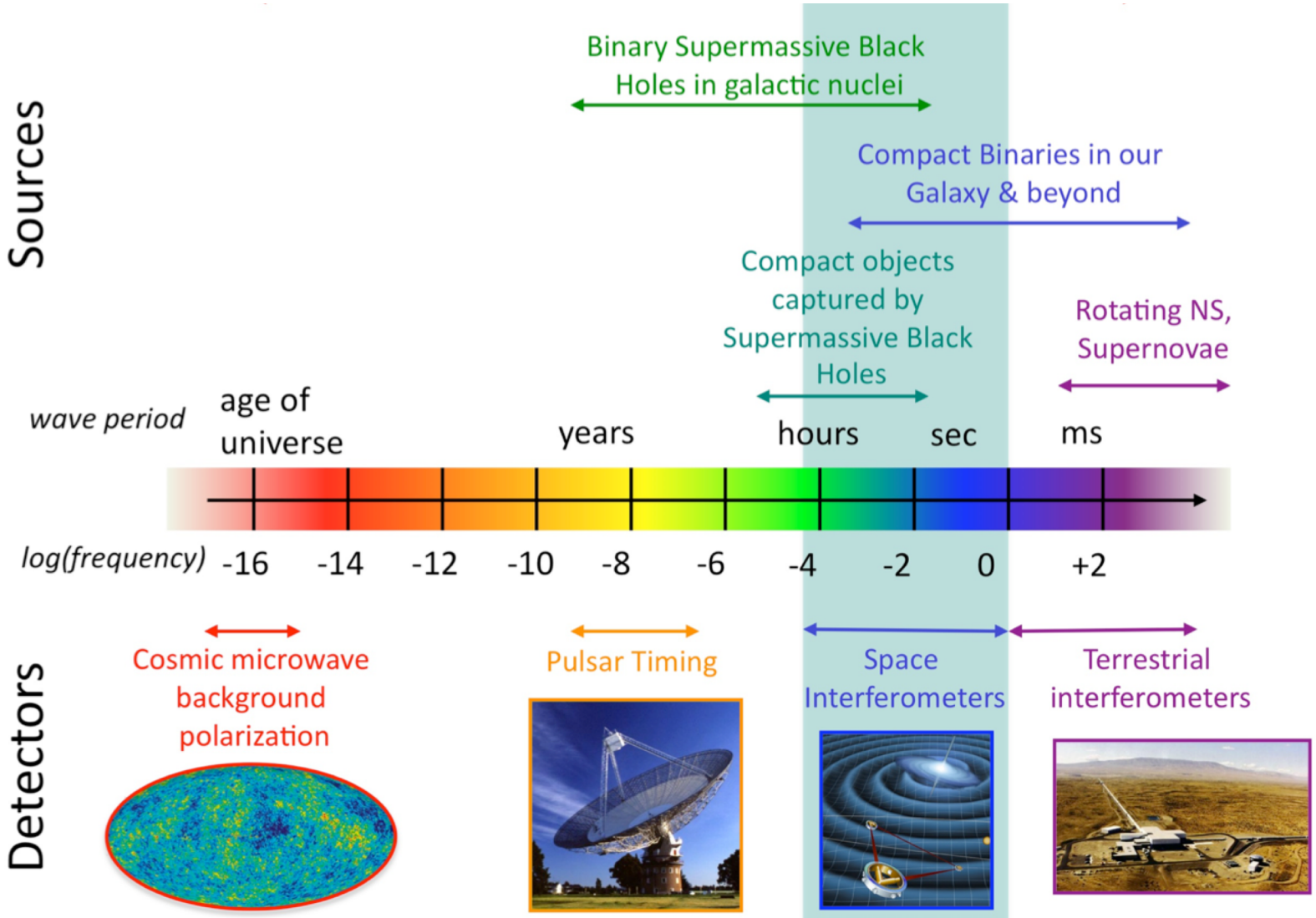
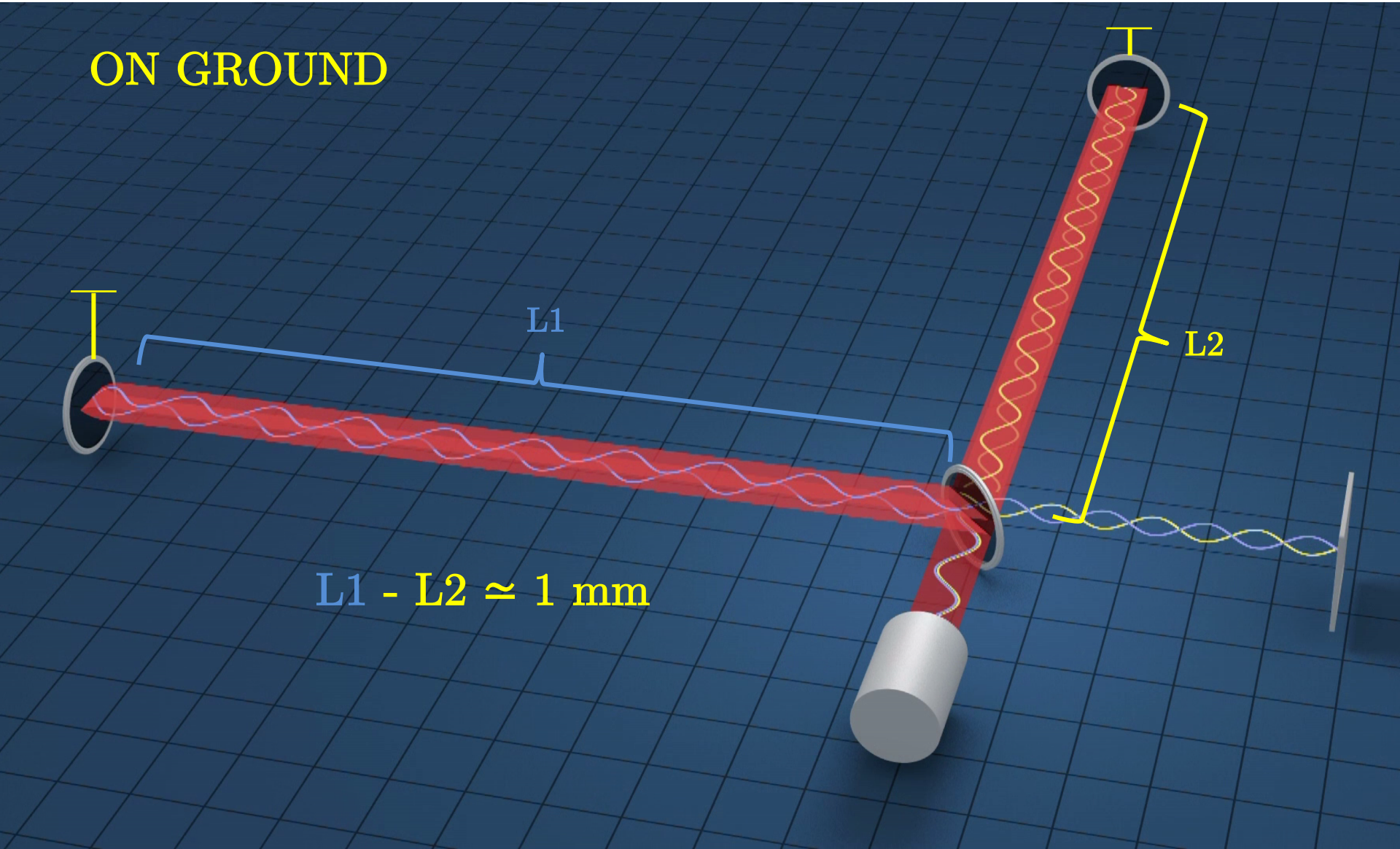
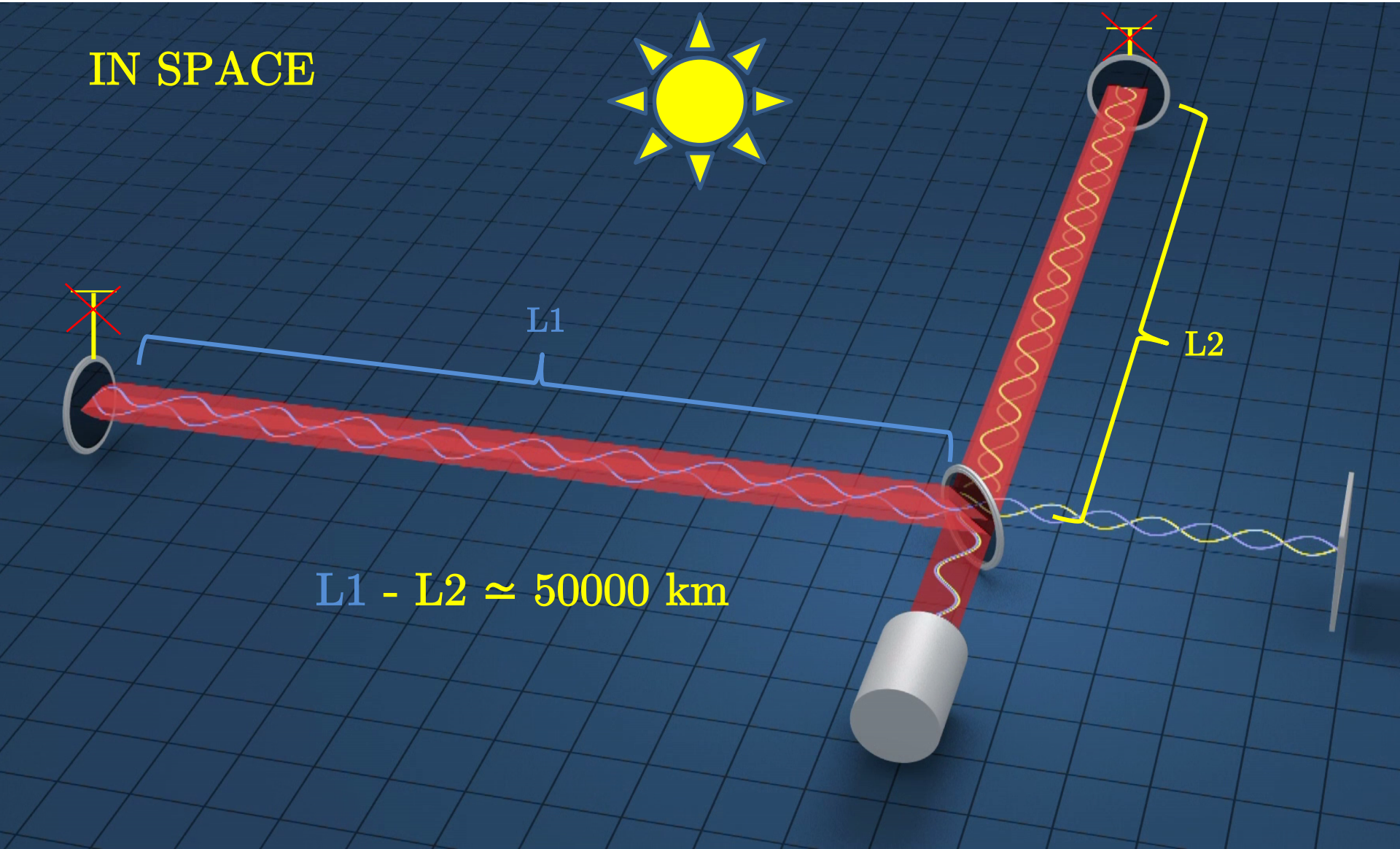
The Gravitational waves spectrum



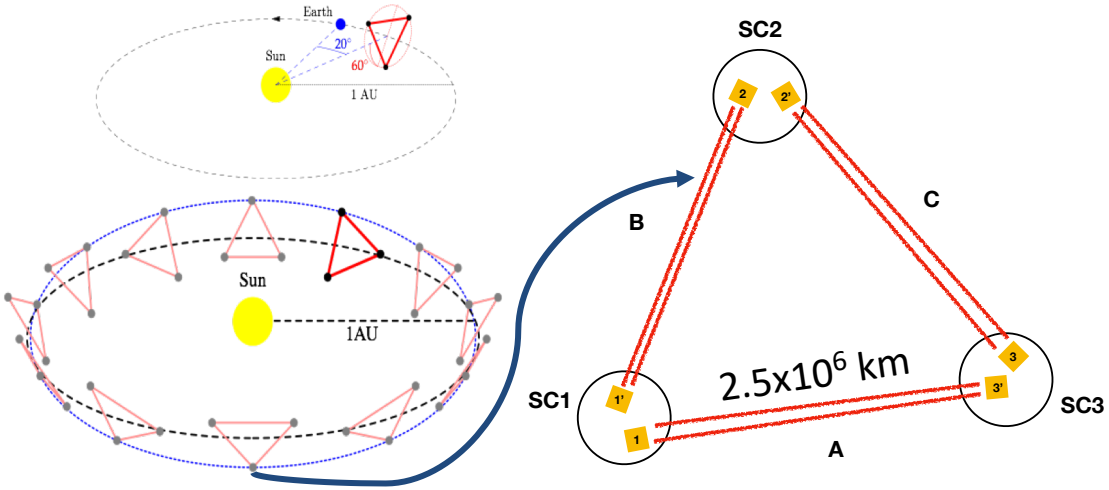
Freely-falling supended mirrors and “equal” arms

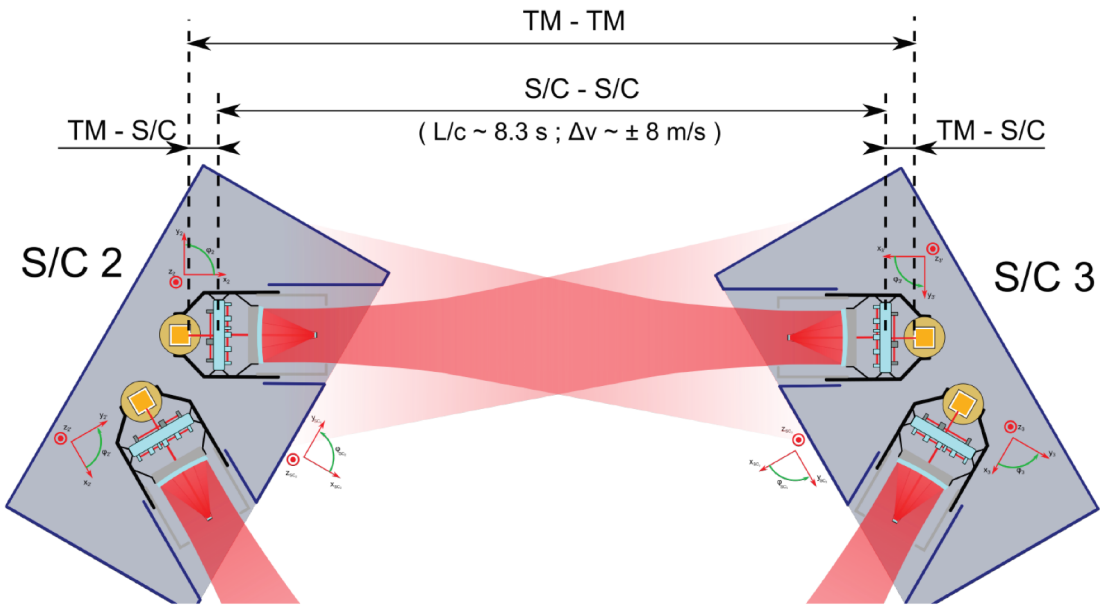


“Orbiting” mirrors and no pendulum!



LISA: the Laser Interferometer Space Antenna



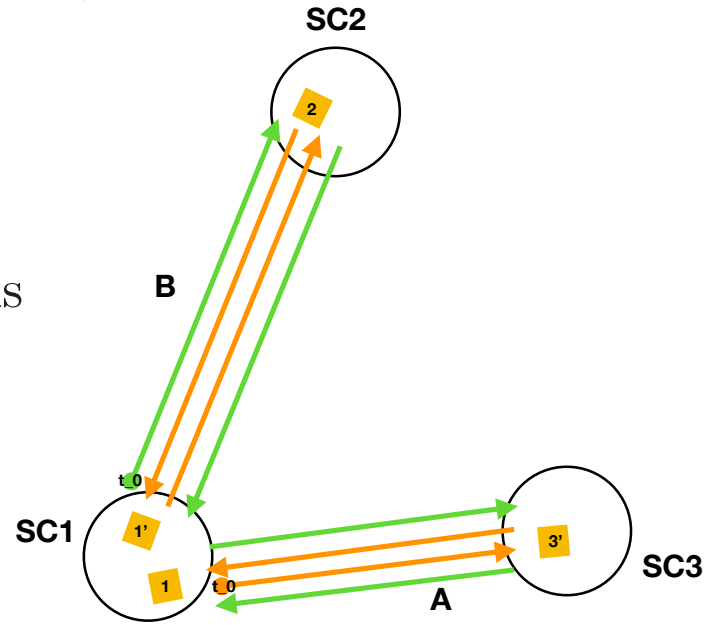


- Heliocentric orbit, Earth-trailing
- ~10^6 km IFO, Drag-free SC
- MOSA (Moving Optical Sub-Assemby): Telescope, Optical bench, Gravity Reference Sensor
- 2 W 1064 nm lasers
- 30 cm telescope
- transponder instead of reflection (100 pW at far SC)
- Split interferometry

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

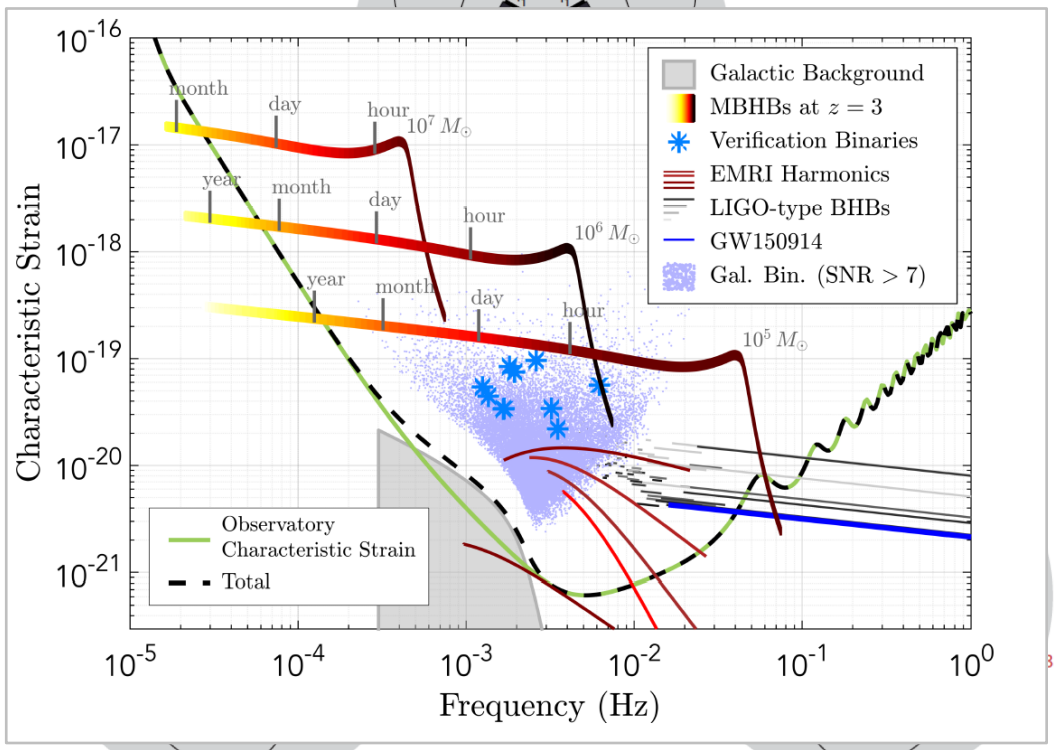
Noise is composed by "IFO noise + acceleration noise"

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

laser freq noise

displacement noise

acceleration noise



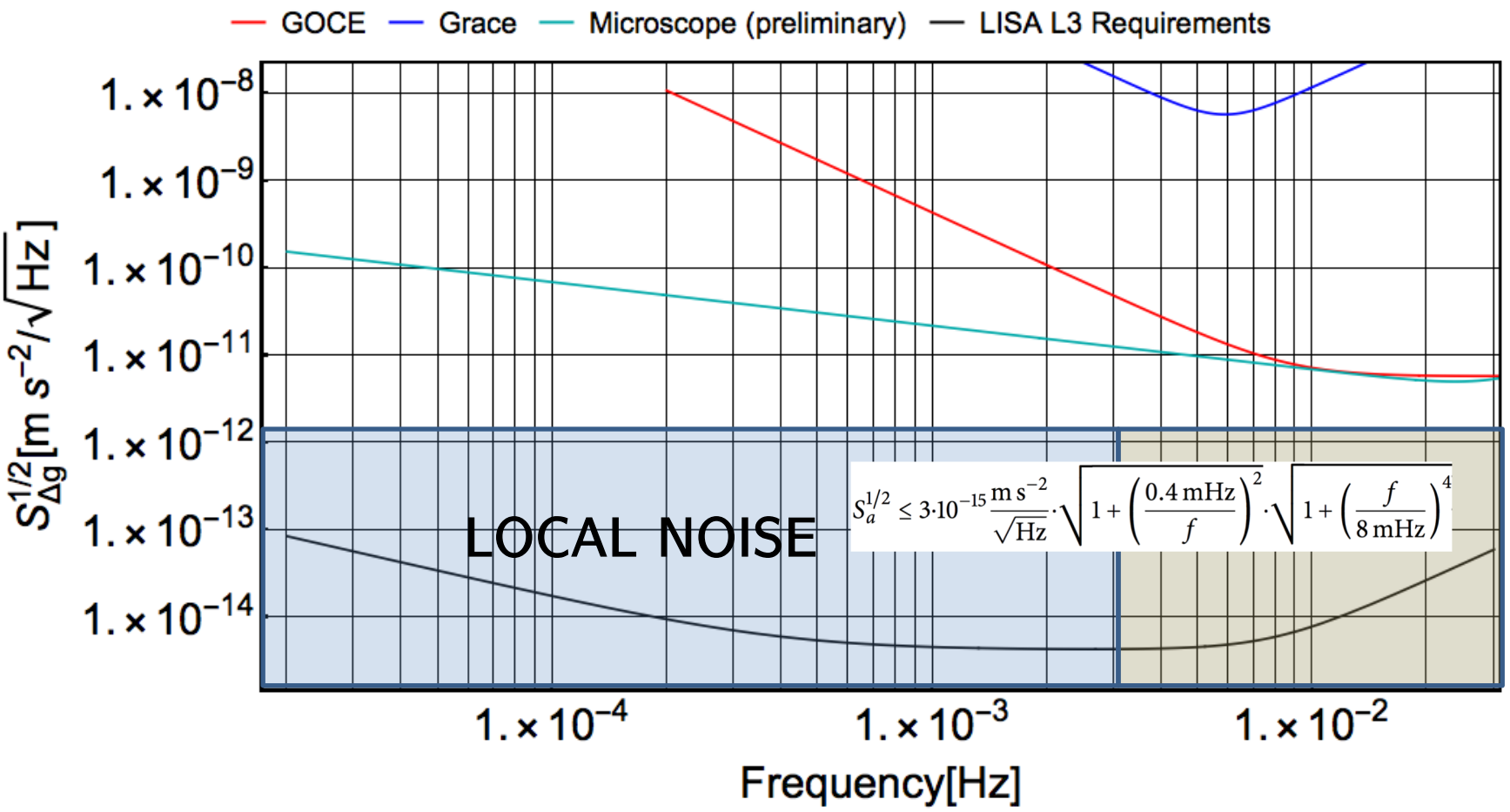
Requirements

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

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



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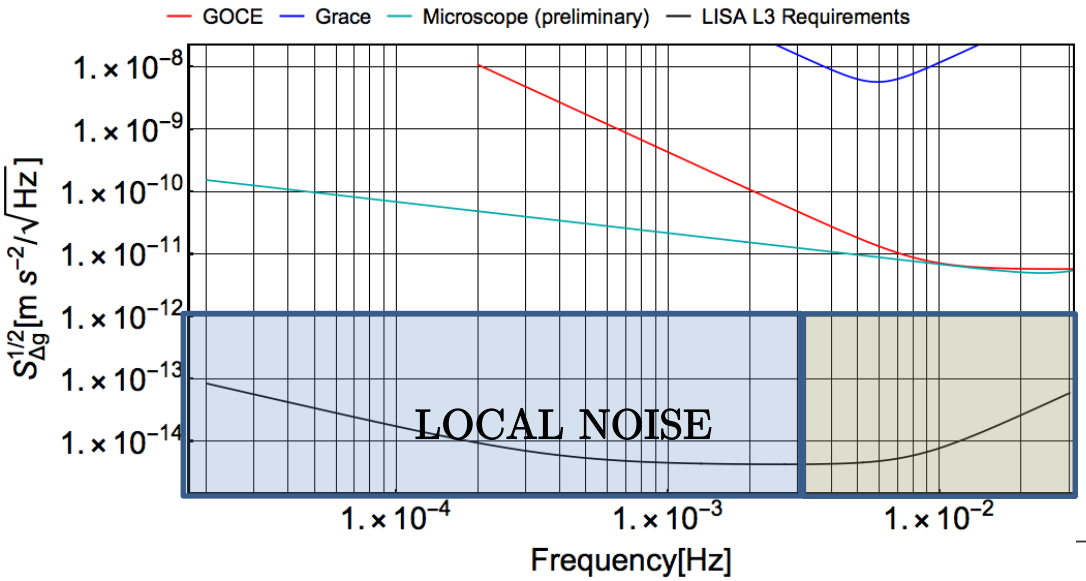
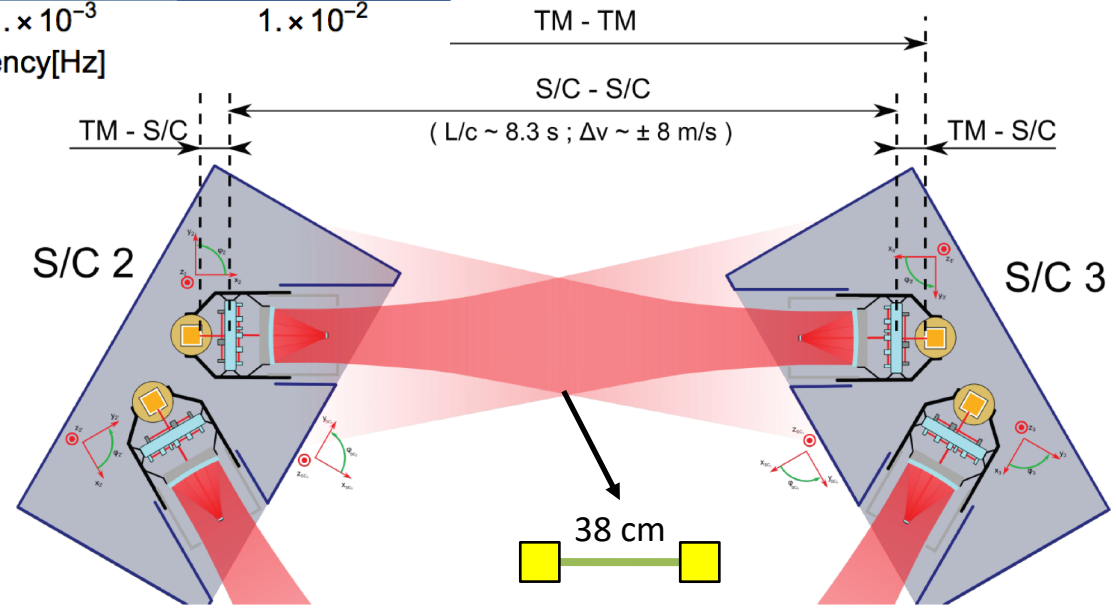
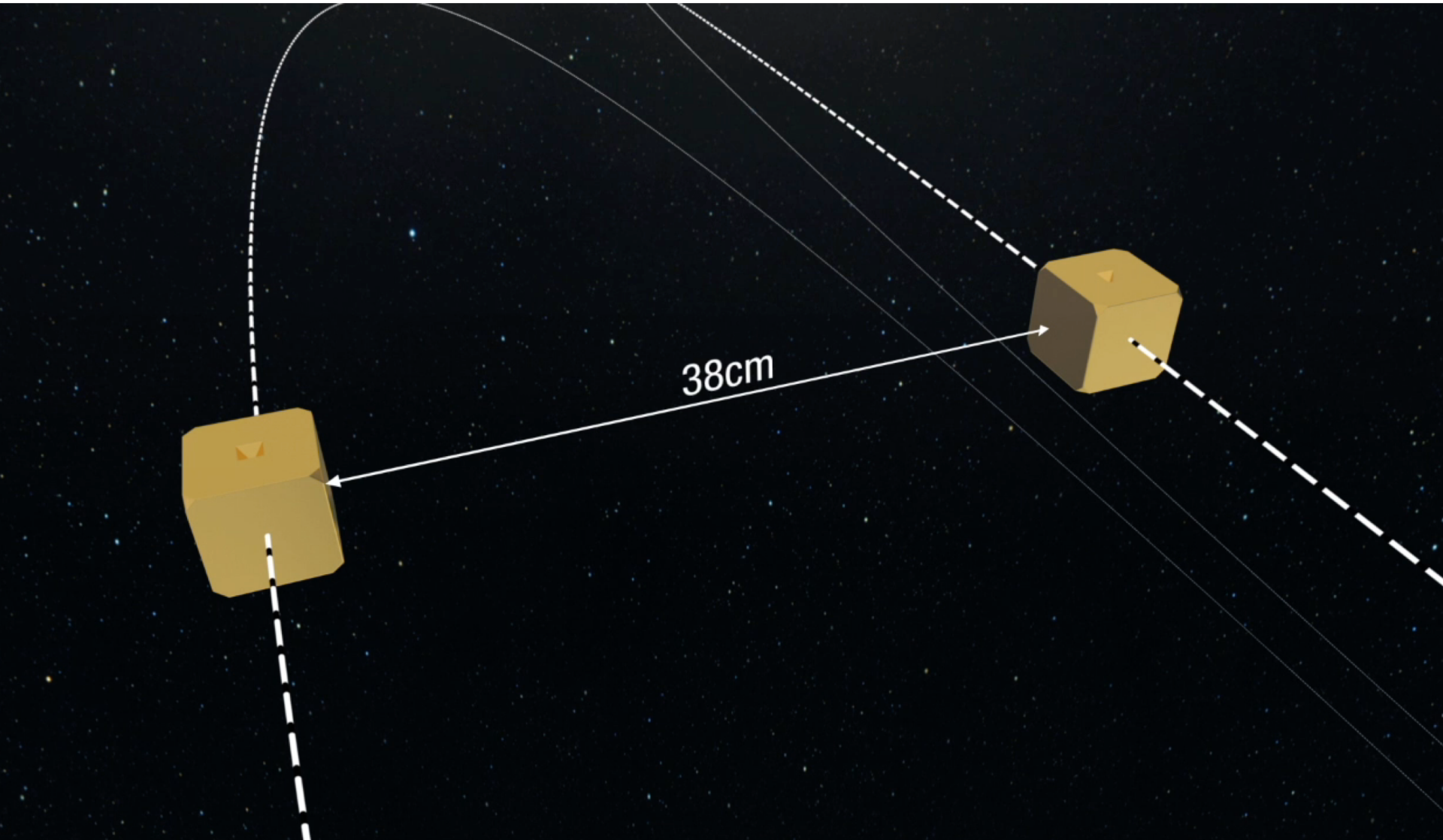
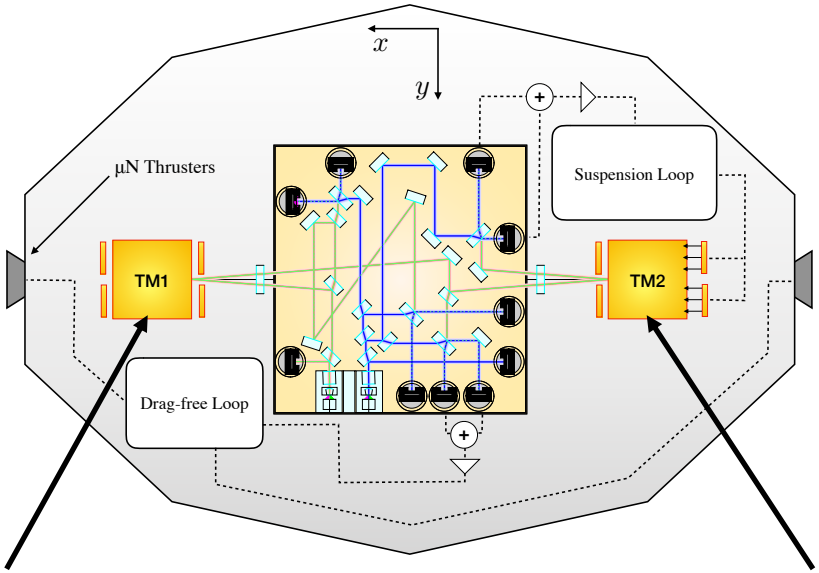




LISA Pathfinder: the LISA technology demonstrator



LISA Pathfinder working principle



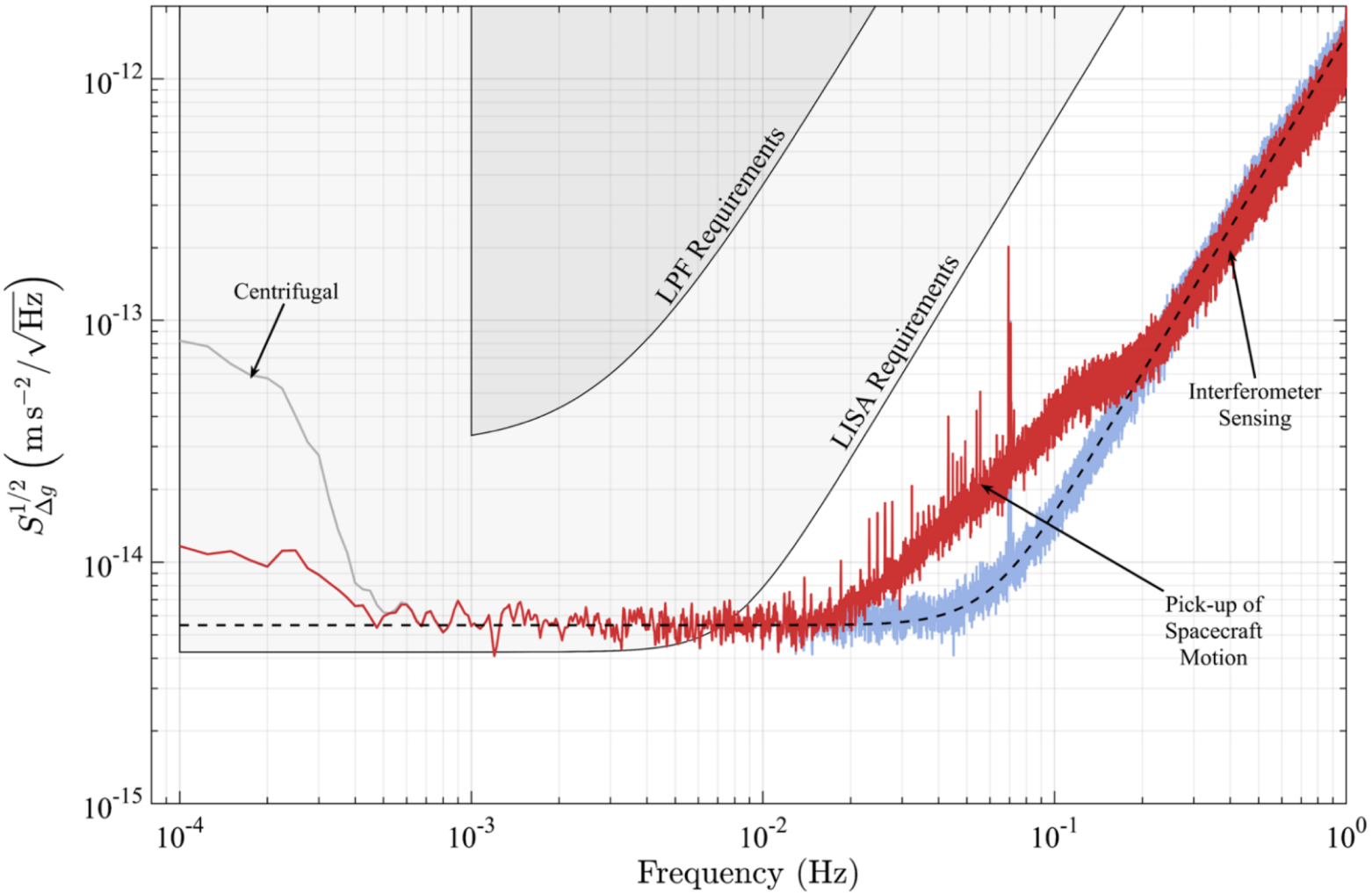
- Drag-free satellite
- Slow capacitive controller via audio-frequencies AC voltages
- Picometre interferometry

$$\ddot{x}_1(t) = f_{sc} - \omega_1^2 x_1 + g_1 \qquad \ddot{x}_2(t) = f_{sc} + f_{2,cmd} - \omega_2^2 x_2 + g_2$$

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

Need to be calibrated

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



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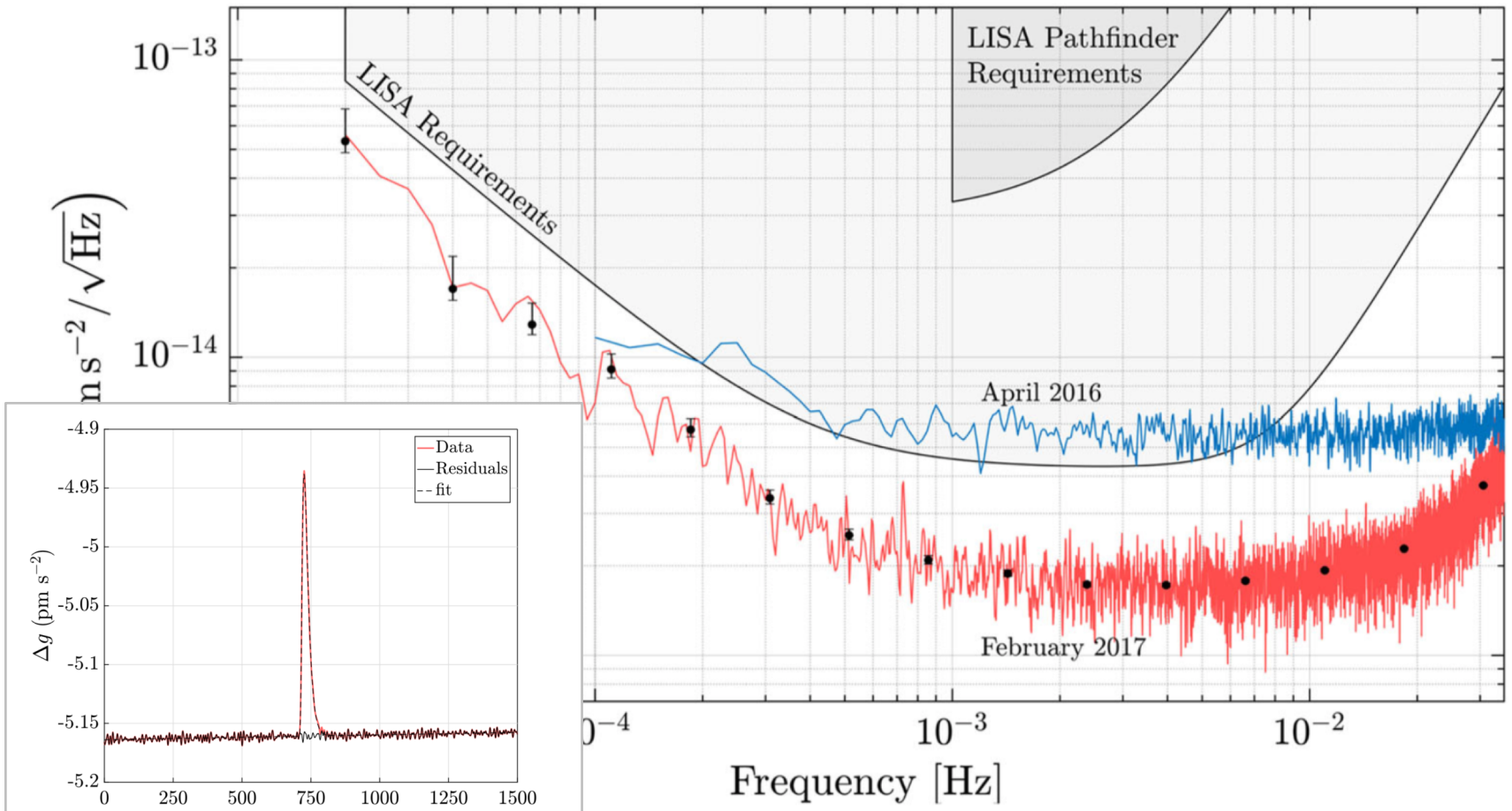
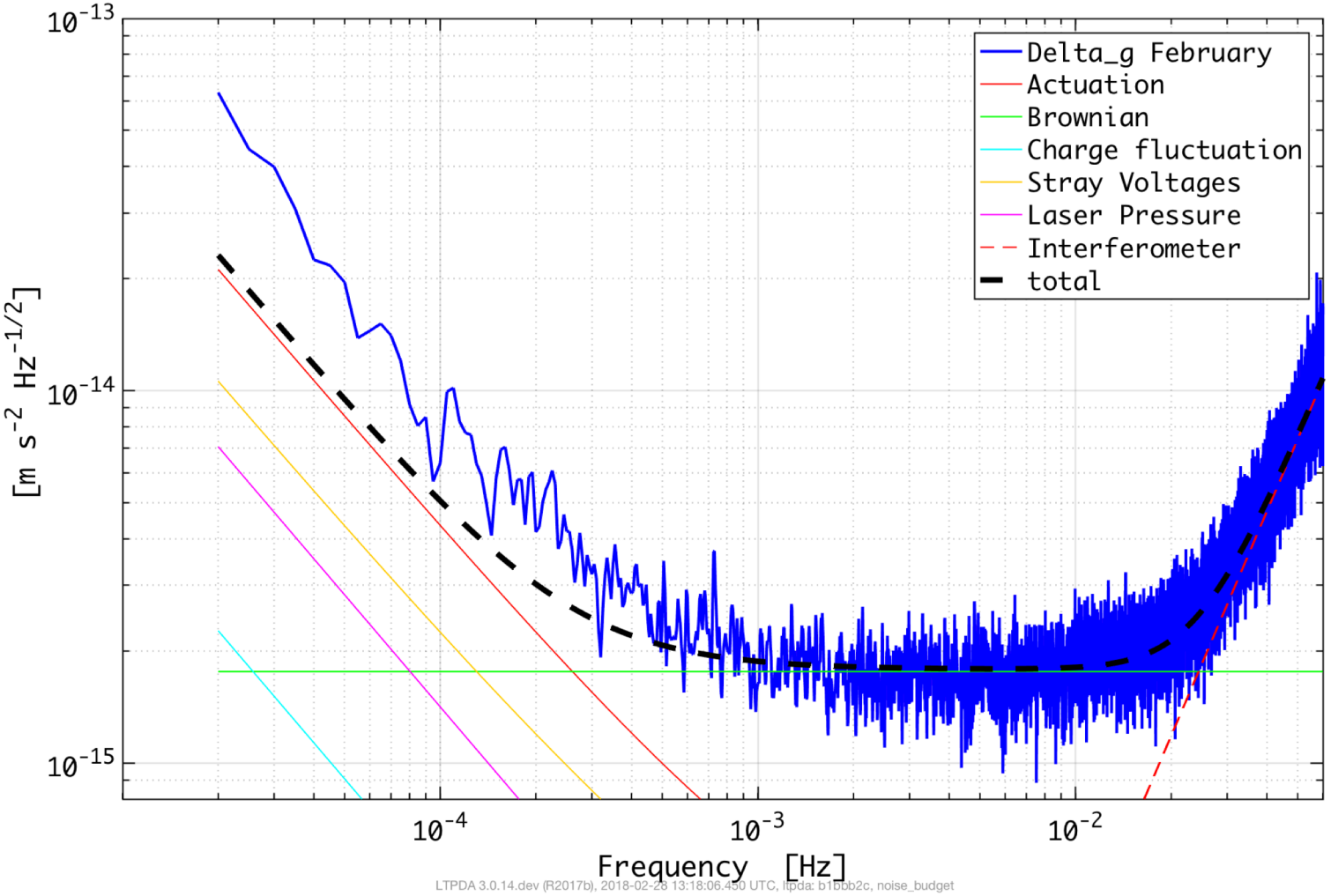
Editors' Suggestion | Featured in Physics

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



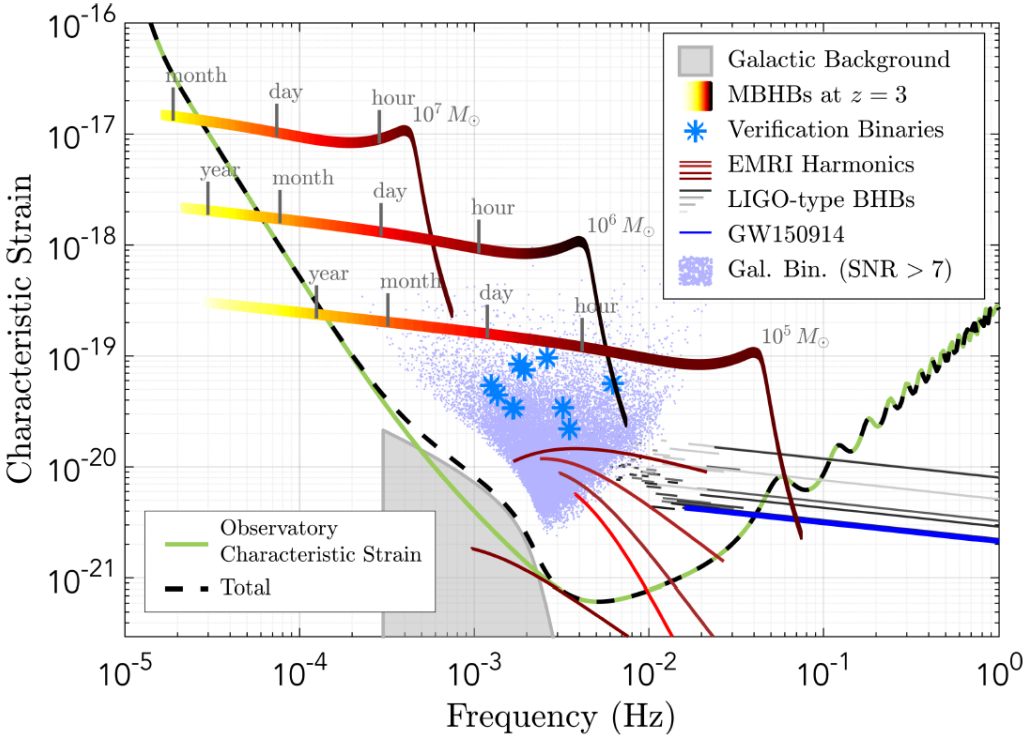
Modeled forces do not fully explain noise



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

- ~$10 \div 10^2$ SMBHBs
- ~$1 \div 10^3$ EMRIs
- ~10^5 resolved galaxy binaries
- ~10^6 of unresolved
- LIGO/Virgo sources
- Discovery potentials

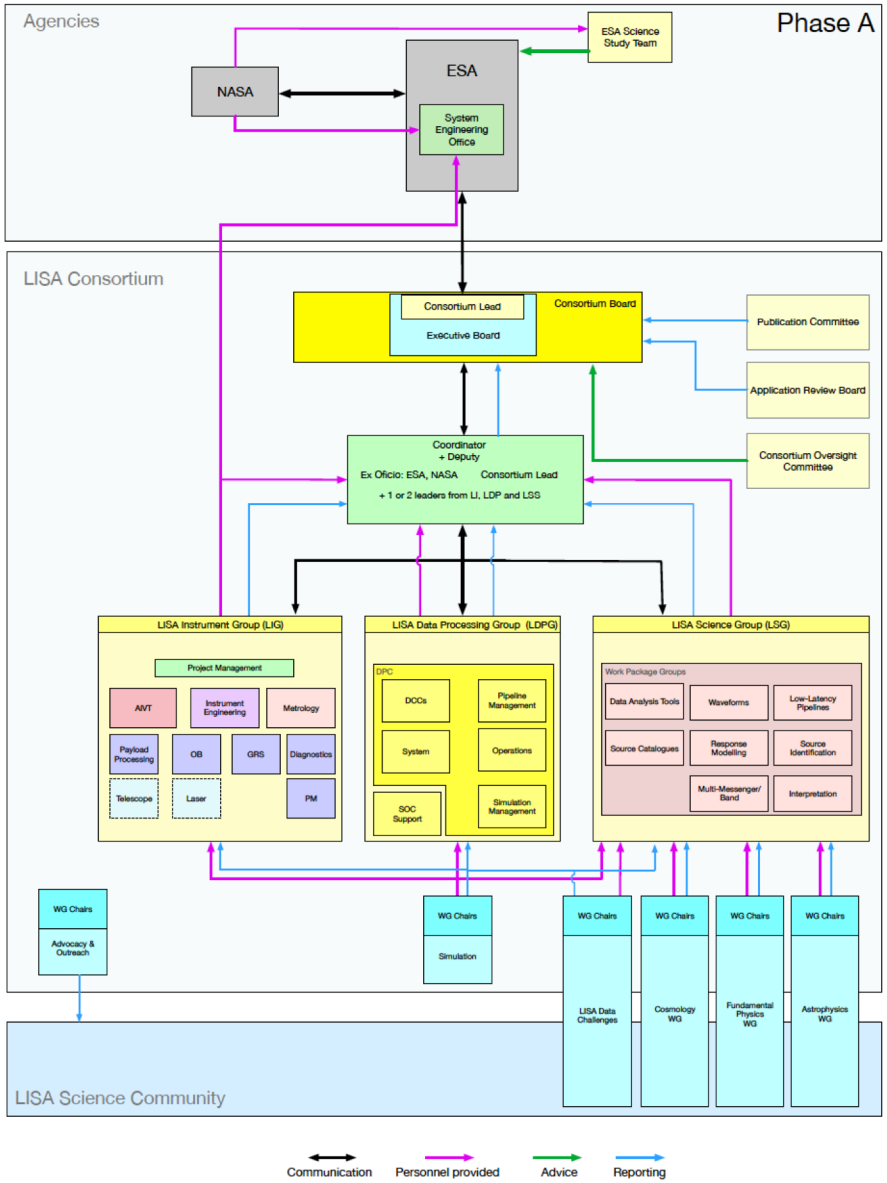
- Global fit in a huge high dimensional space, together with instrumental noise and GW stochastic foreground

LISA mission status

Timeline

October 2013:	Selection of "The Gravitational Universe" as science theme for the 3rd 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)

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/