LISA
Science, Instrument and Status

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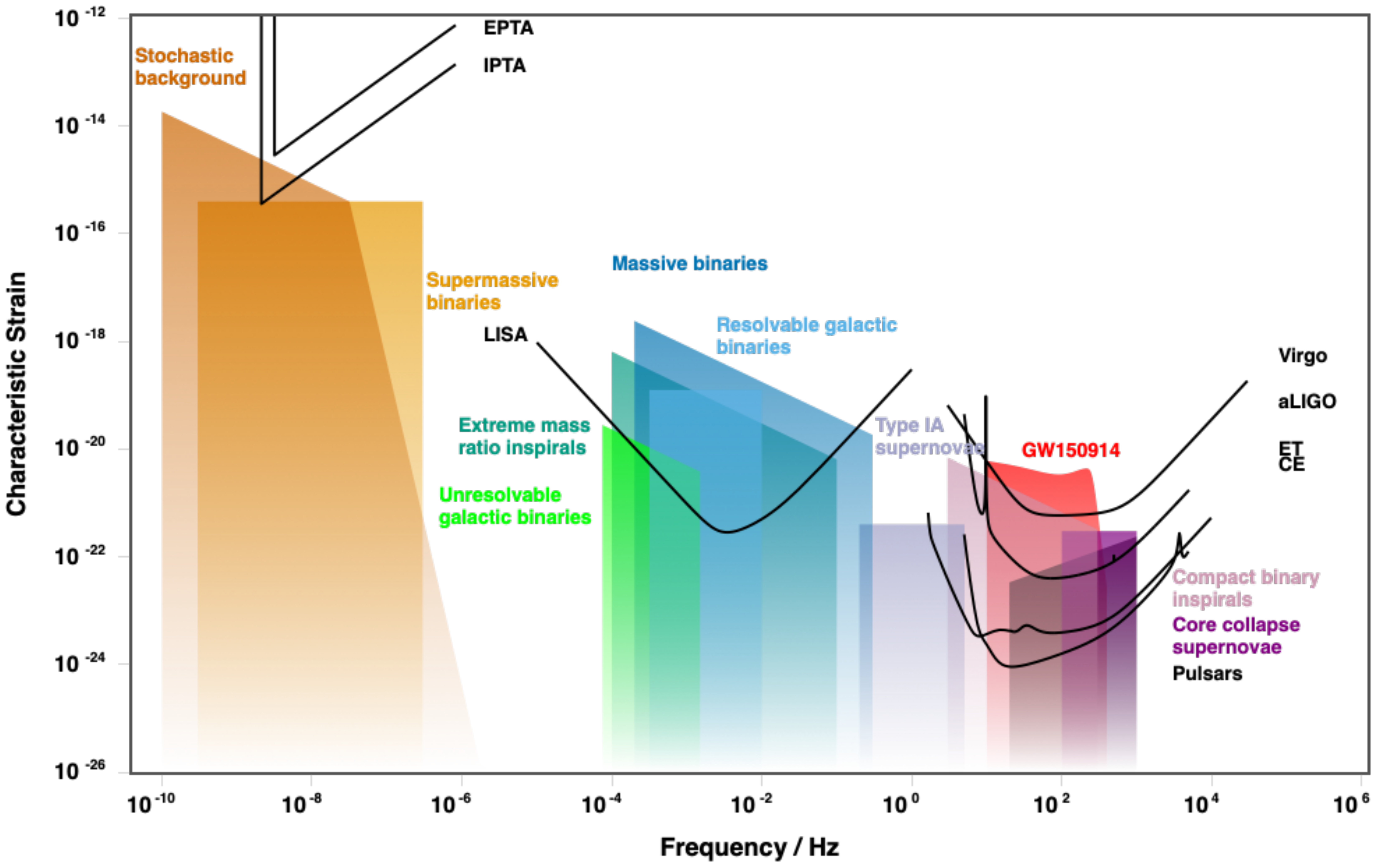
Current and planned Gravitational wave observatories

Ground-based:

- aLIGO, Virgo, Kagra
- Future: ET, CE
  - Operational: 203?

Space-based:

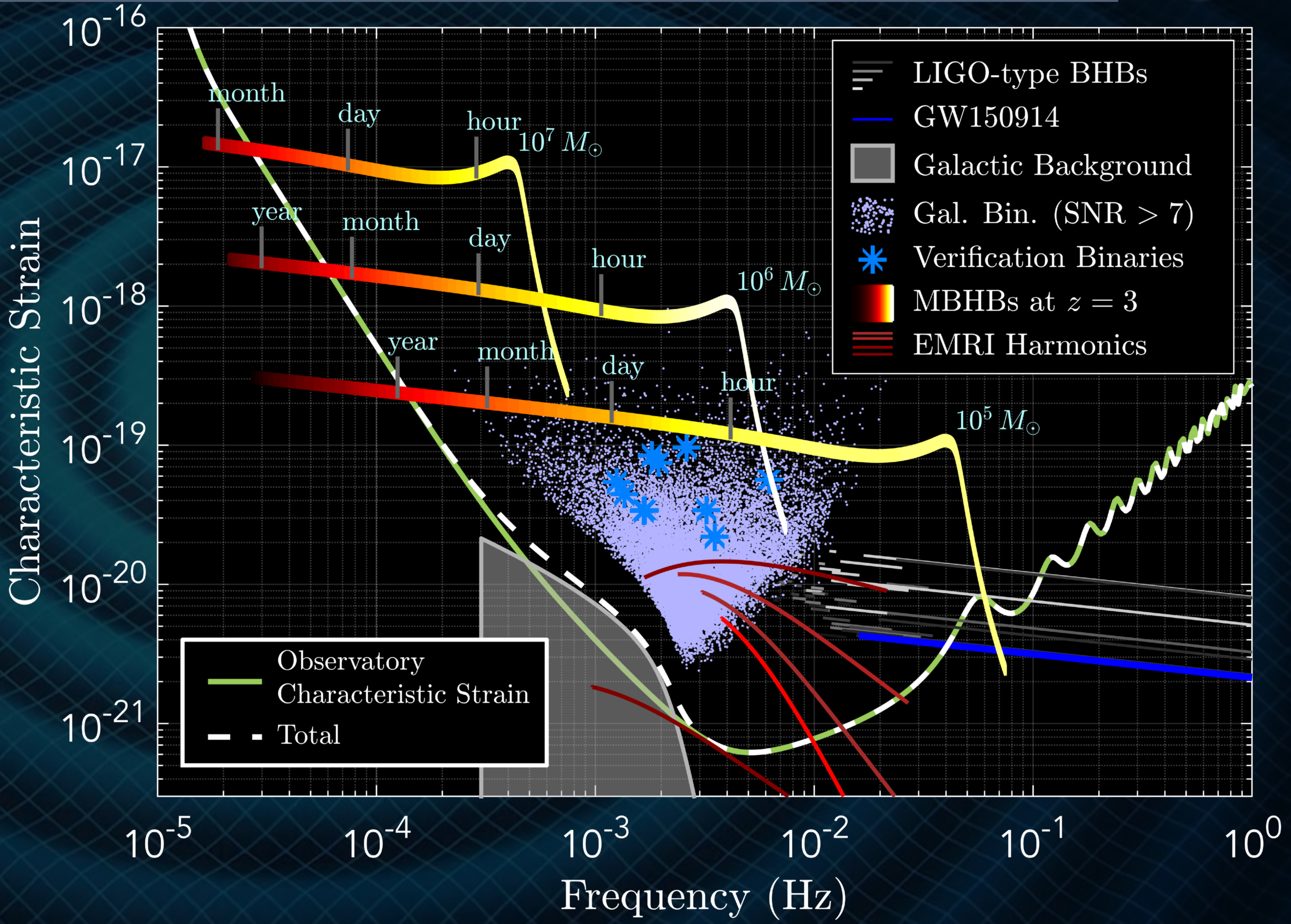
- LISA
  - Launch 203?
  - mHz-Range
    - ~10^4 - 10^7 solar masses



Credit: Cristopher Berry (https://faculty.wcas.northwestern.edu/cpb2759/GWPlotter/)

LISA Science

- Expected signals cover
  - Range of frequencies
  - Range of amplitudes
  - Range of durations
- LISA is an all-sky, "always on", observatory
  - Multitude of signals present in the data at all times

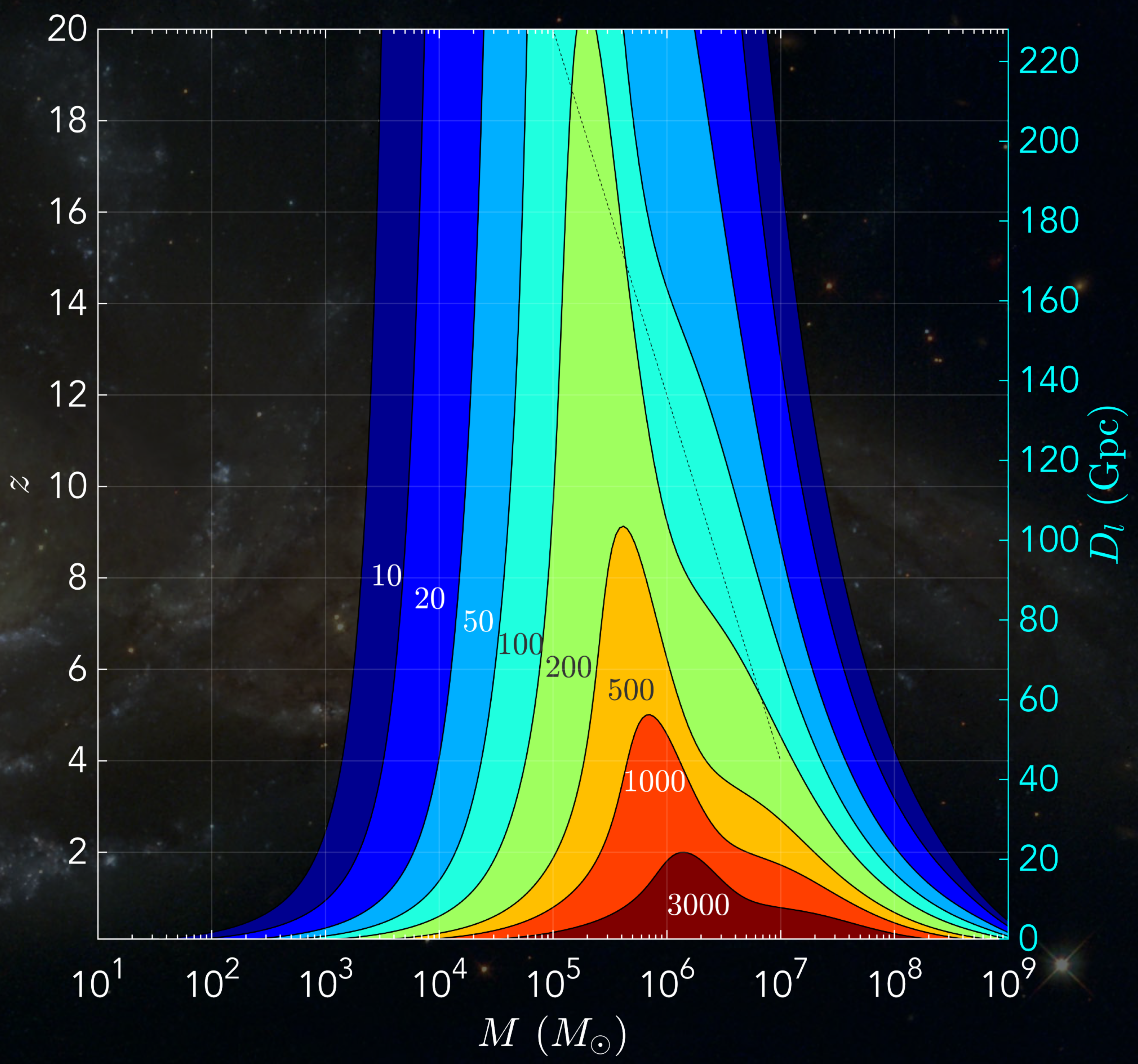


Massive Black Holes 10^2 to 10^8 $M_\odot$

Most galaxies host massive black hole at center.

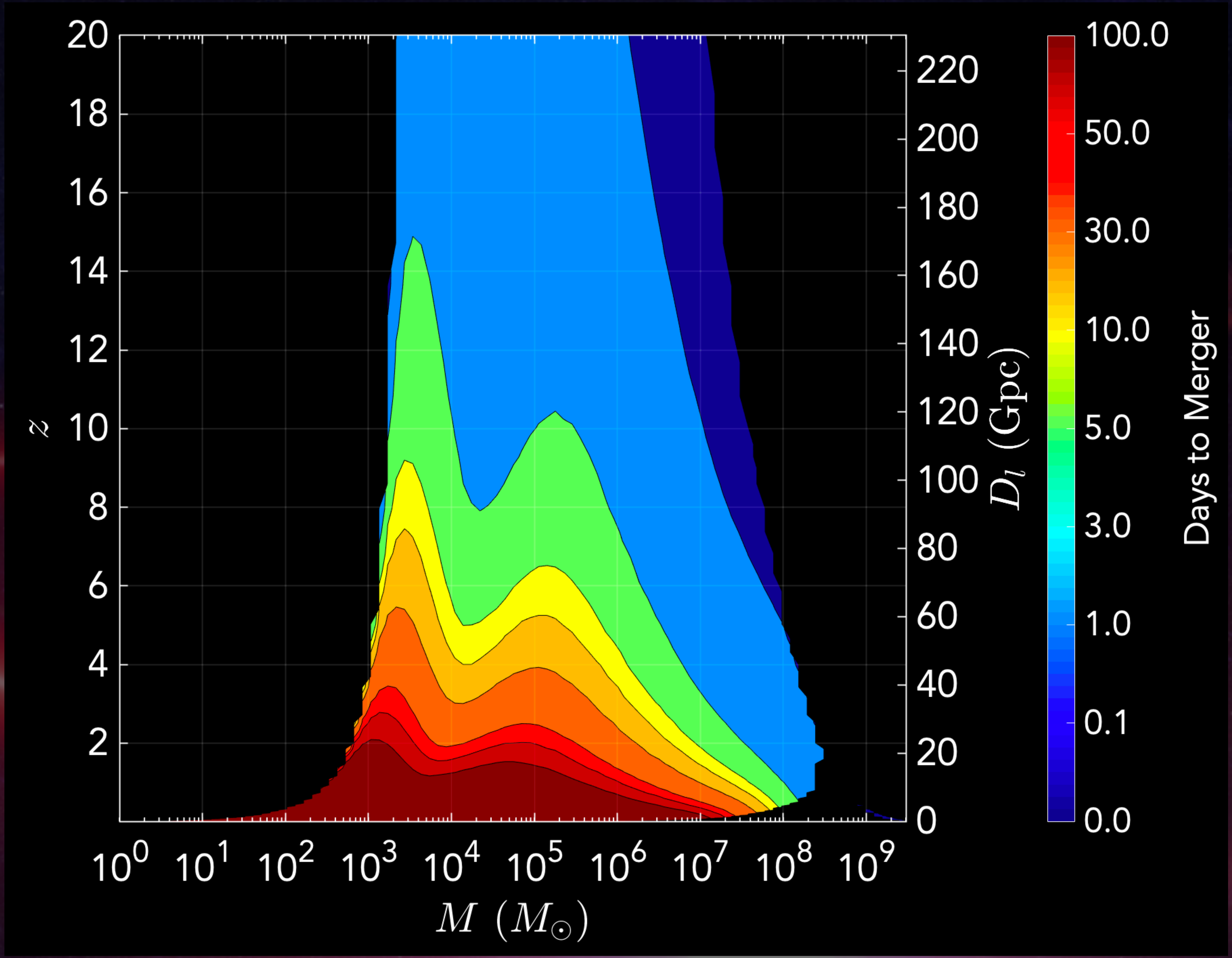
How did they grew?

- EM Accretion or repeated mergers

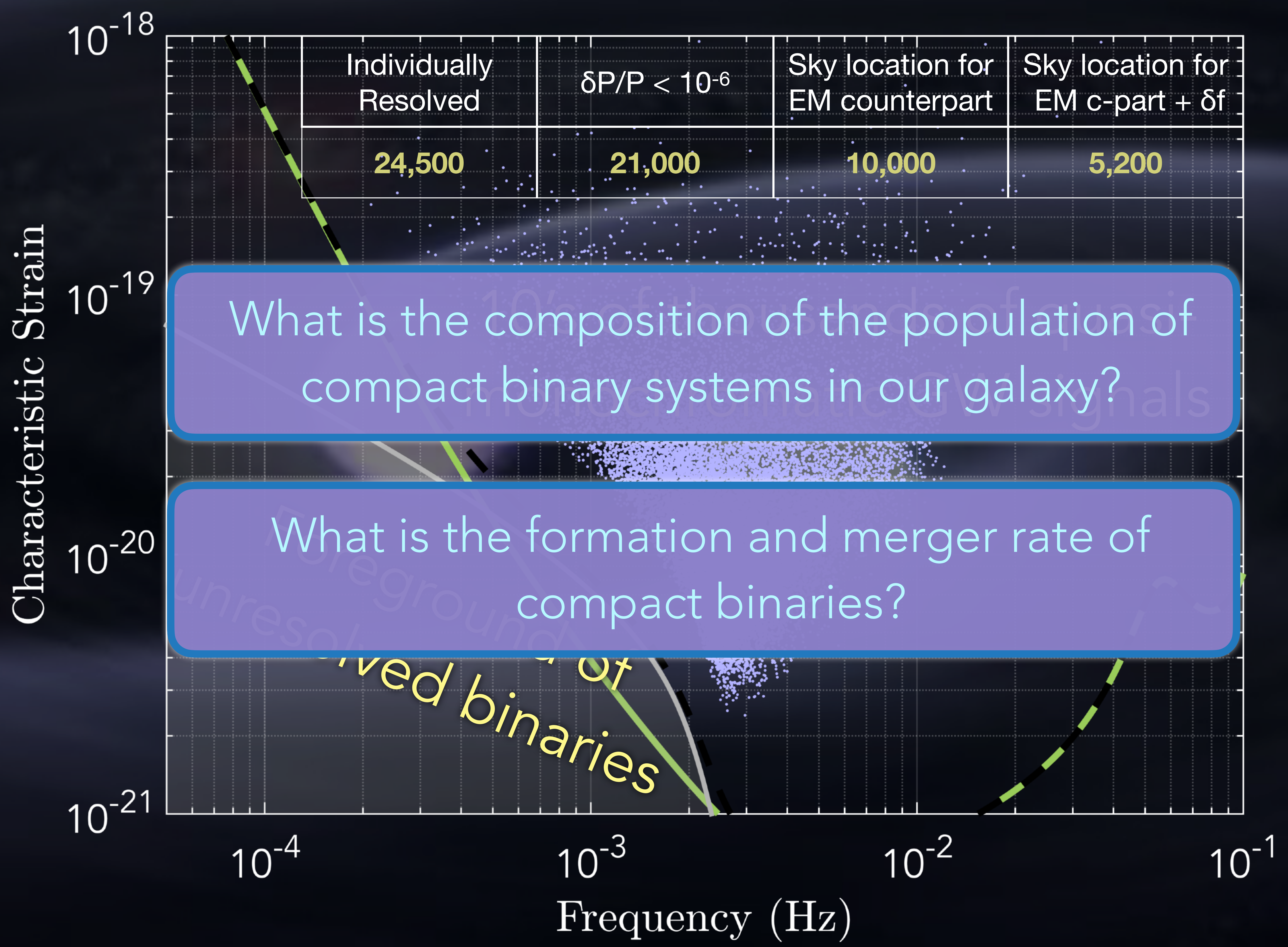


Multi-messenger astronomy with LISA

- For some systems:
  - Observe the inspiral phase for days or weeks
  - Source localisation improves
  - Alerts for EM follow-up



S01: Ultra-Compact Binaries in our Galaxy

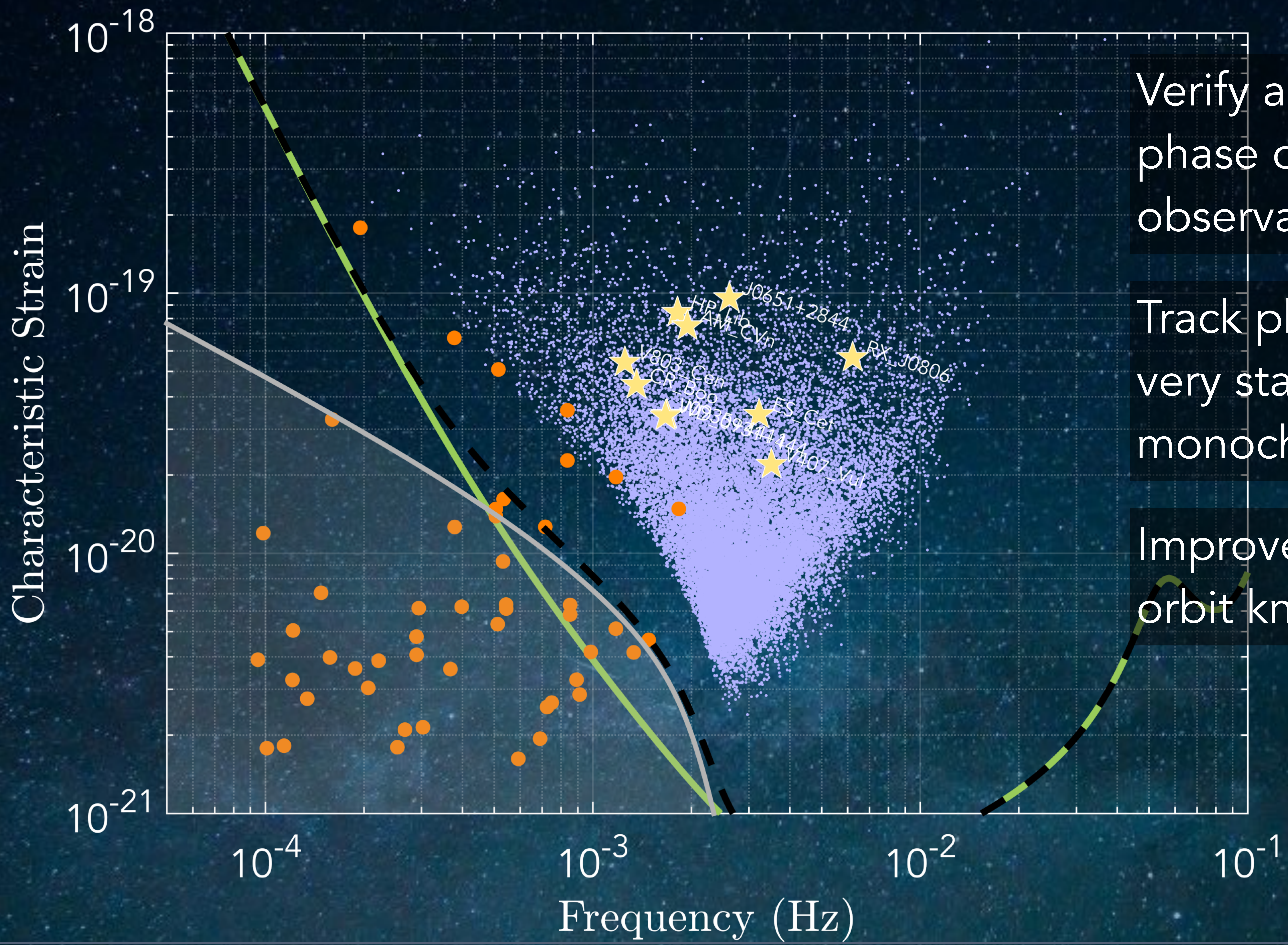


Individually Resolved	$\delta P/P < 10^{-6}$	Sky location for EM counterpart	Sky location for EM c-part + δf
24,500	21,000	10,000	5,200

What is the composition of the population of compact binary systems in our galaxy?

What is the formation and merger rate of compact binaries?

Verification Binaries as observatory diagnostics

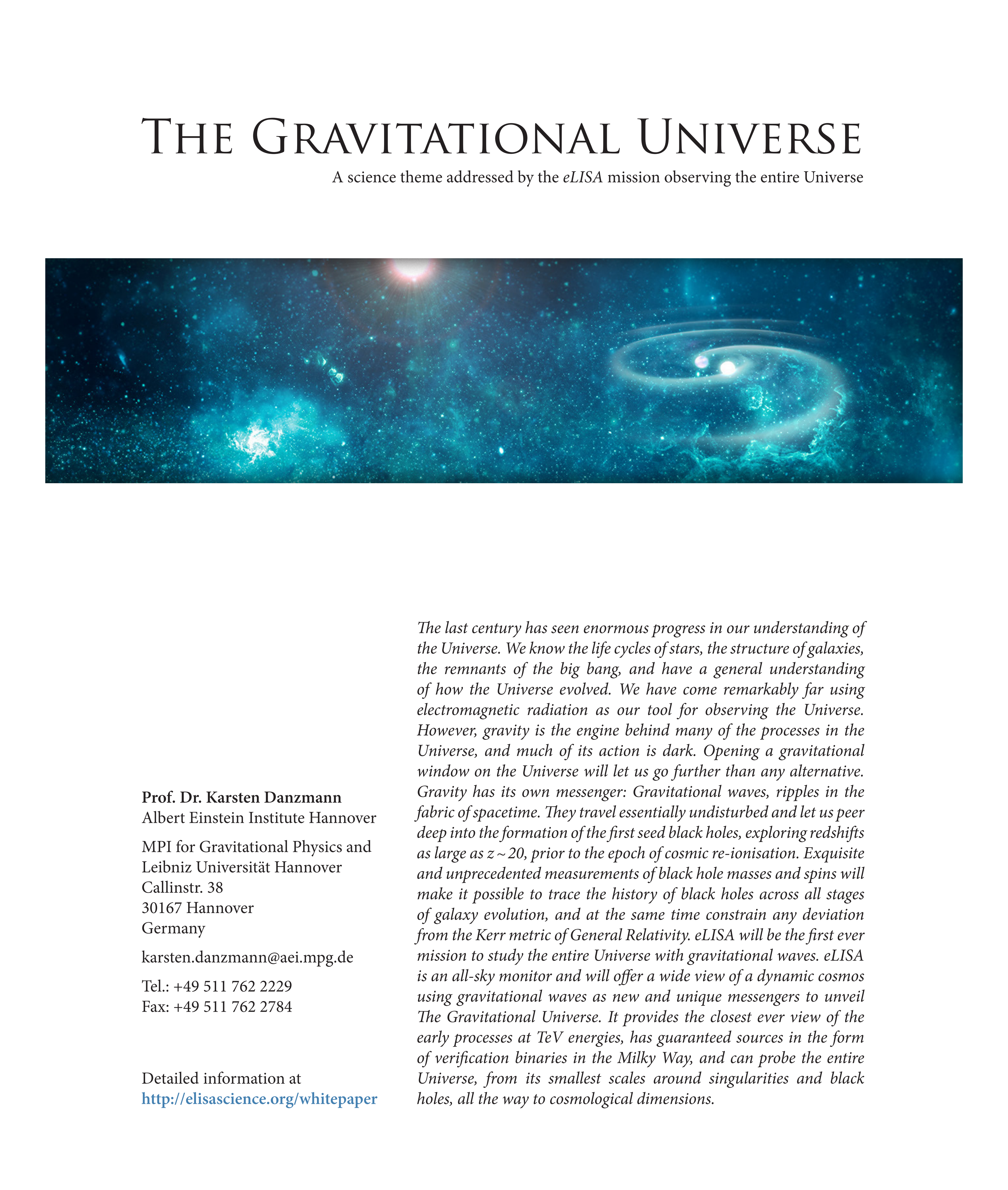


Verify amplitude and phase calibration of observatory outputs

Track phase coherence of very stable monochromatic signal

Improve observatory orbit knowledge

Read more in



THE GRAVITATIONAL UNIVERSE

A science theme addressed by the *eLISA* mission observing the entire Universe

The last century has seen enormous progress in our understanding of the Universe. We know the life cycles of stars, the structure of galaxies, the remnants of the big bang, and have a general understanding of how the Universe evolved. We have come remarkably far using electromagnetic radiation as our tool for observing the Universe. However, gravity is the engine behind many of the processes in the Universe, and much of its action is dark. Opening a gravitational window on the Universe will let us go further than any alternative. Gravity has its own messenger: Gravitational waves, ripples in the fabric of spacetime. They travel essentially undisturbed and let us peer deep into the formation of the first seed black holes, exploring redshifts as large as z ~ 20, prior to the epoch of cosmic re-ionisation. Exquisite and unprecedented measurements of black hole masses and spins will make it possible to trace the history of black holes across all stages of galaxy evolution, and at the same time constrain any deviation from the Kerr metric of General Relativity. eLISA will be the first ever mission to study the entire Universe with gravitational waves. eLISA is an all-sky monitor and will offer a wide view of a dynamic cosmos using gravitational waves as new and unique messengers to unveil The Gravitational Universe. It provides the closest ever view of the early processes at TeV energies, has guaranteed sources in the form of verification binaries in the Milky Way, and can probe the entire Universe, from its smallest scales around singularities and black holes, all the way to cosmological dimensions.

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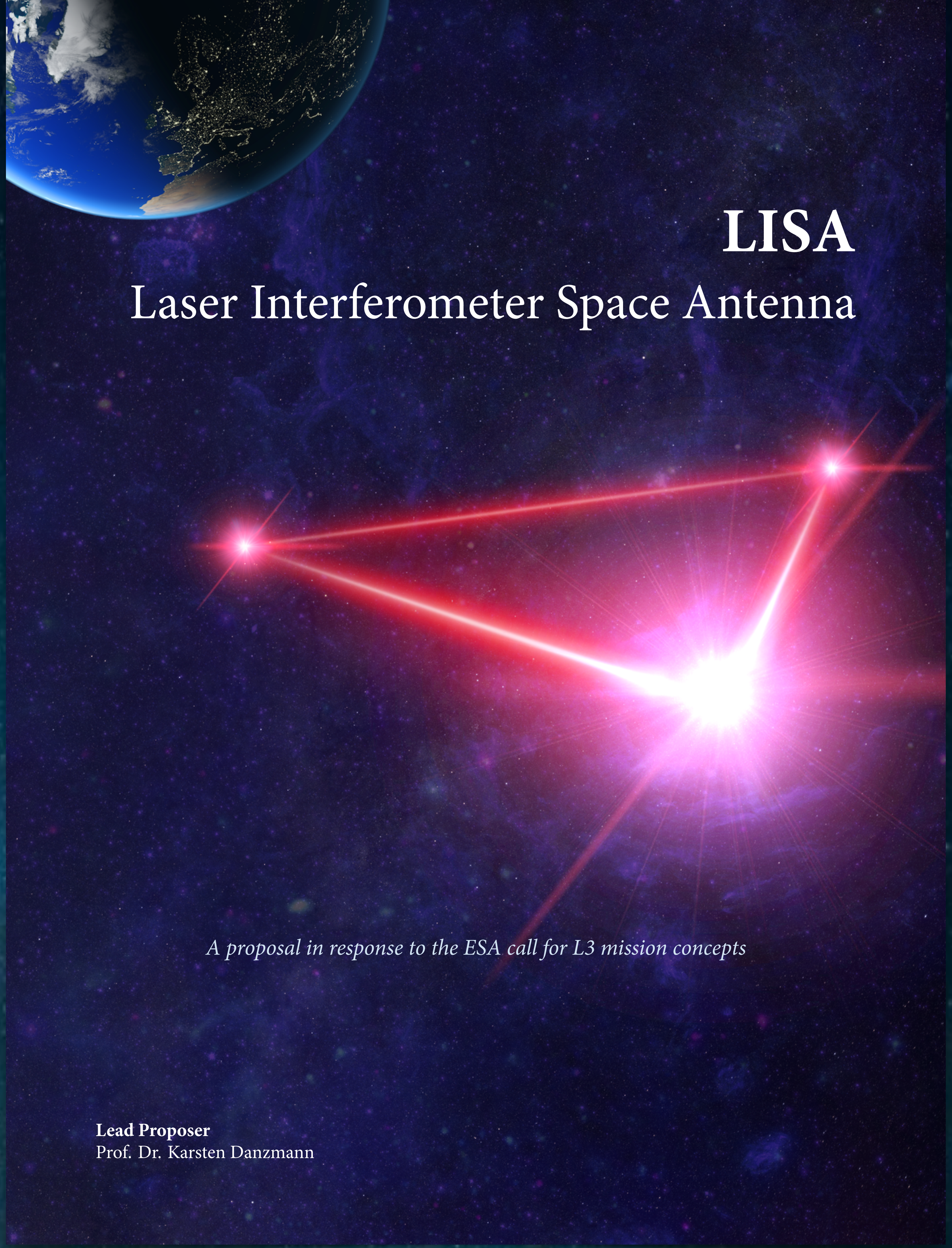
Detailed information at
http://elisascience.org/whitepaper

https://arxiv.org/abs/1305.5720

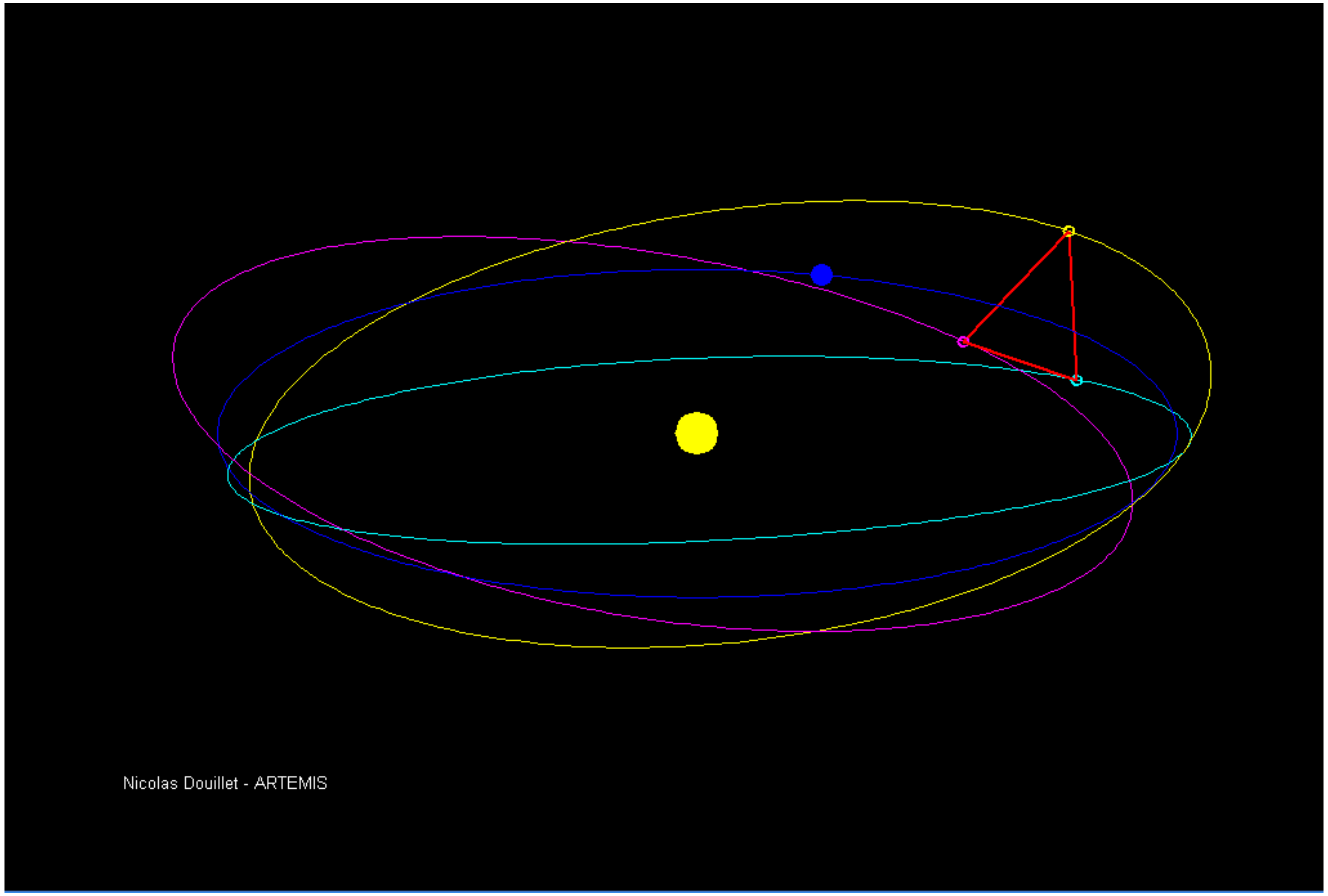
https://arxiv.org/abs/1702.00786

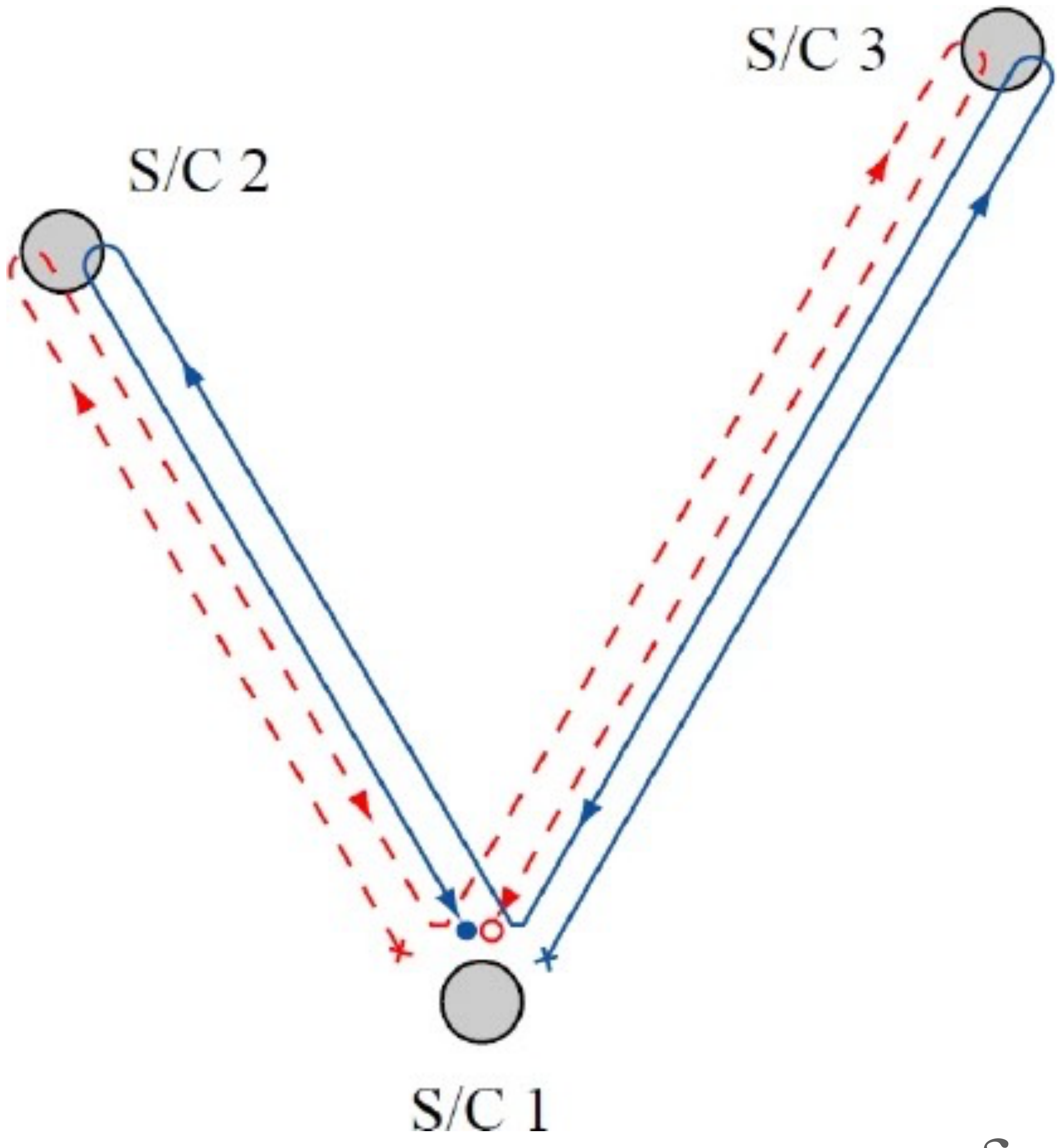


LISA Interferometer Space Antenna

Mission concept:

- 3 S/C triangle
- 2.5 Gm arm length
  - 6 links
  - 2 TM per S/C
- heliocentric orbits
  - minimal arm lengths changes
    - $2.5\,\mathrm{Gm} \pm 30\,\mathrm{Mm}$
    - $v_{rel} \approx \pm 10\,\mathrm{m/s}$
- heterodyne interferometry
  - measure changes in phases of laser beat signals

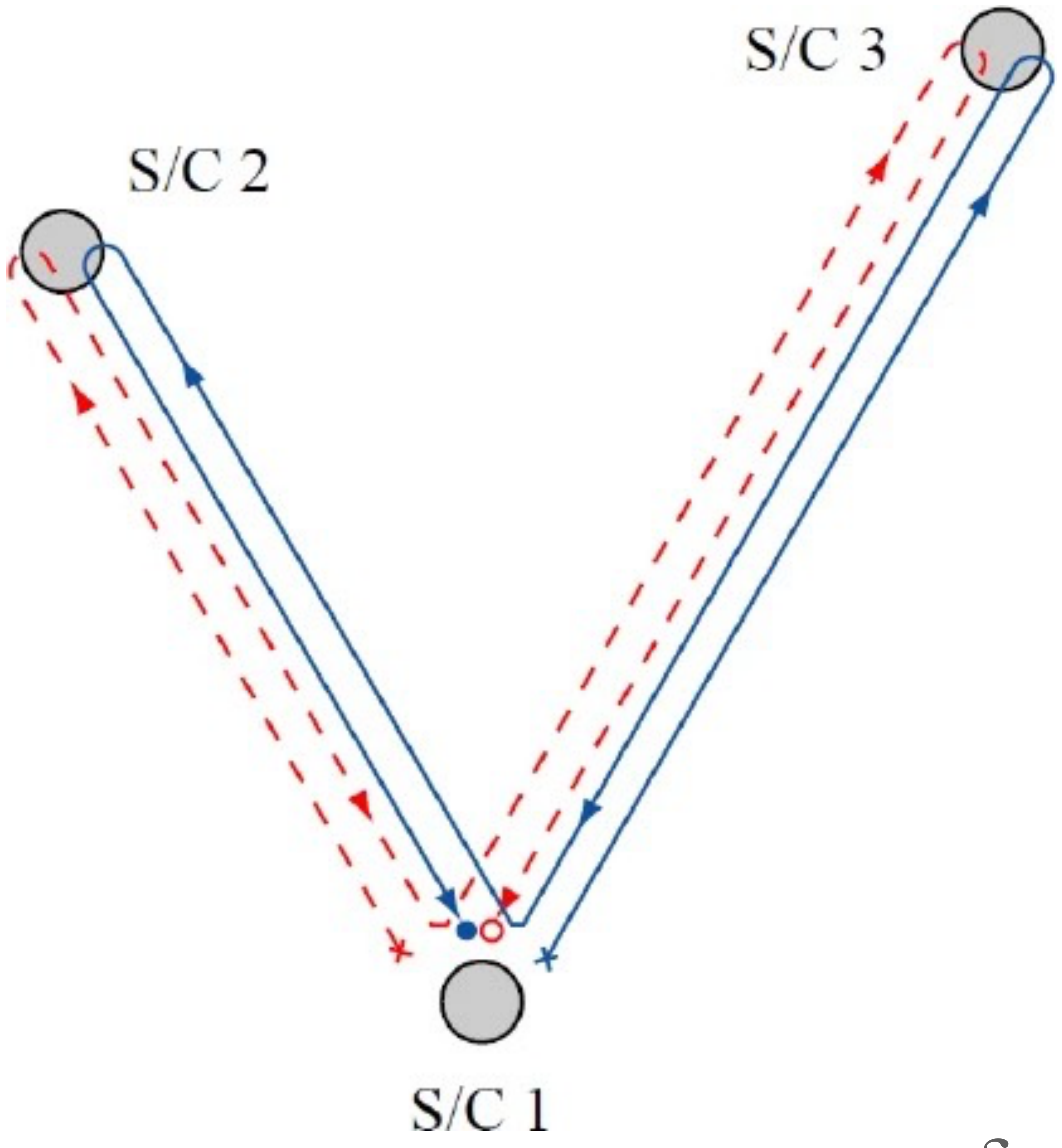




Laser frequency noise: $$\delta l_{\delta\nu} = \frac{\delta\nu}{\nu}\Delta L$$

in unequal arm interferometer

LISA Interferometer Space Antenna



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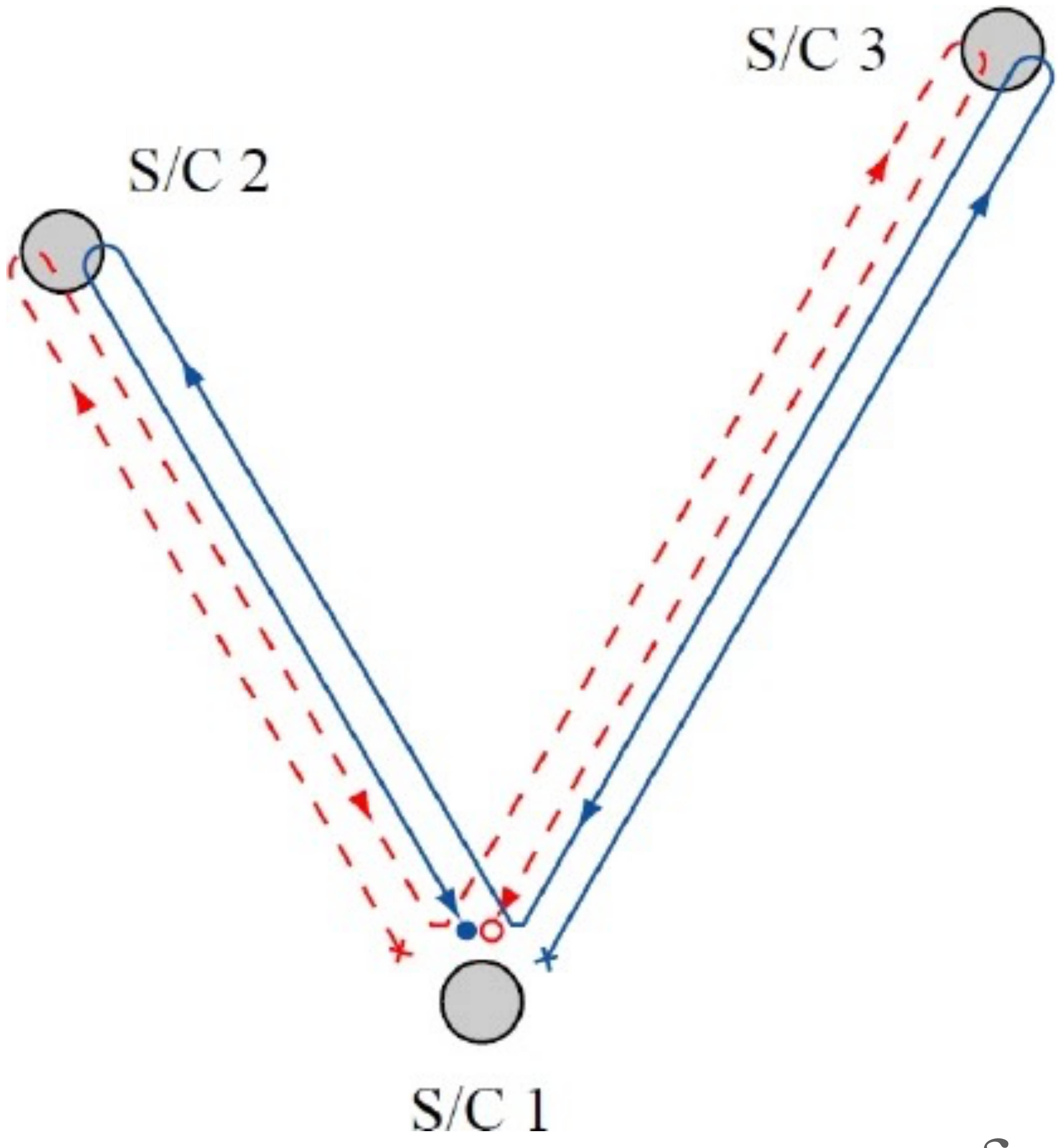
LISA Interferometry:

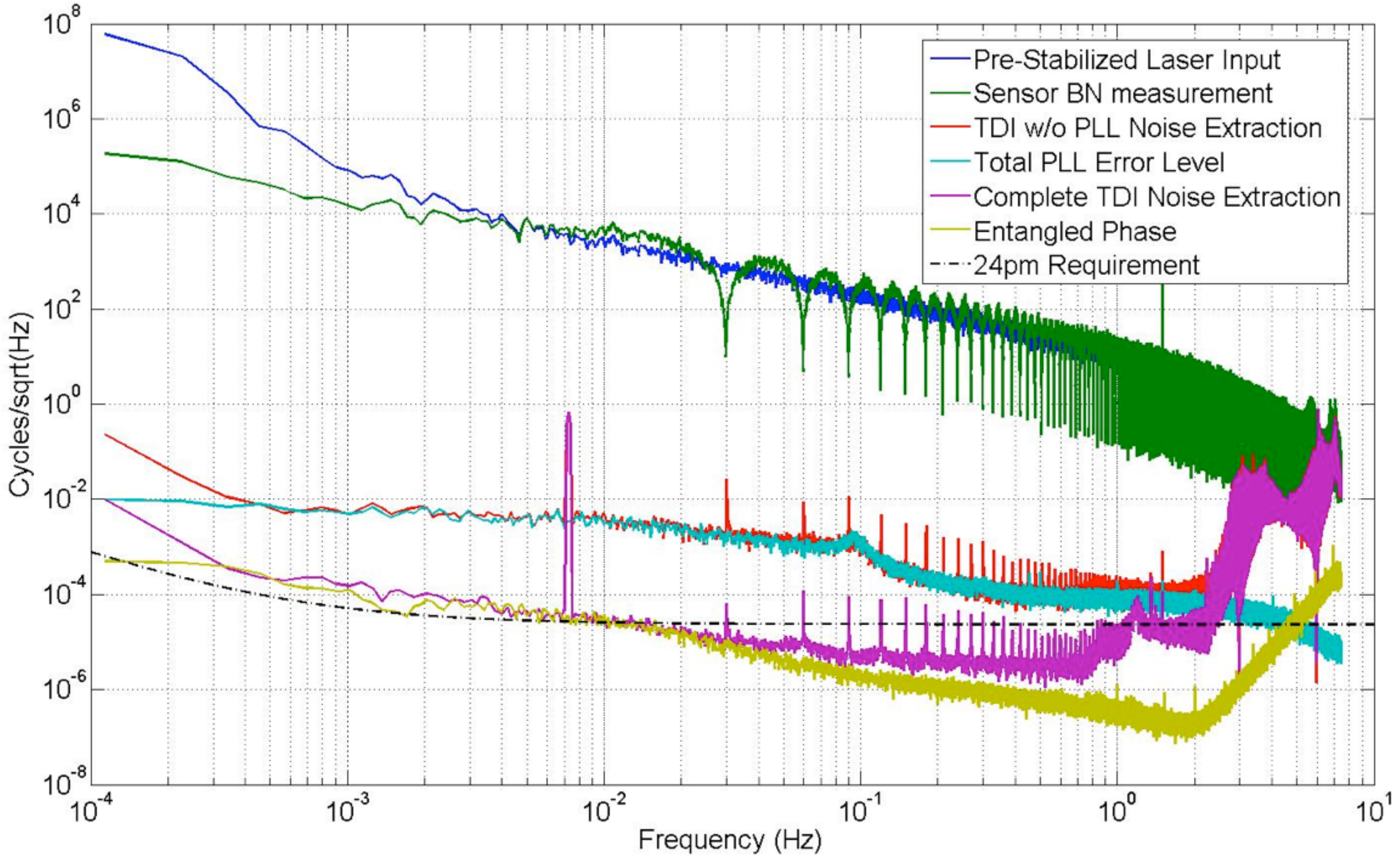
- S/C 1 = Central S/C
- Far S/C 2 & 3 act as transponders
  - $\Phi^{ret}_{2,3}(t) = \Phi^{rec}_{2,3}(t)$
- S/C 1 signals:
  - $S_{12}(t) = \Phi(t) - \Phi(t - \tau_{12})$
  - $S_{13}(t) = \Phi(t) - \Phi(t - \tau_{13})$
- TDI 1.0:
  - $S_{12}(t) - S_{12}(t - \tau_{13}) - S_{13}(t) - S_{13}(t - \tau_{12})$
  - cancels laser frequency noise for static LISA
  - keeps GW signals
- TDI 2.0: needed for dynamic LISA

LISA Interferometer Space Antenna



Time Delay Interferometry @ UF

- create equal arm IFO in postprocessing



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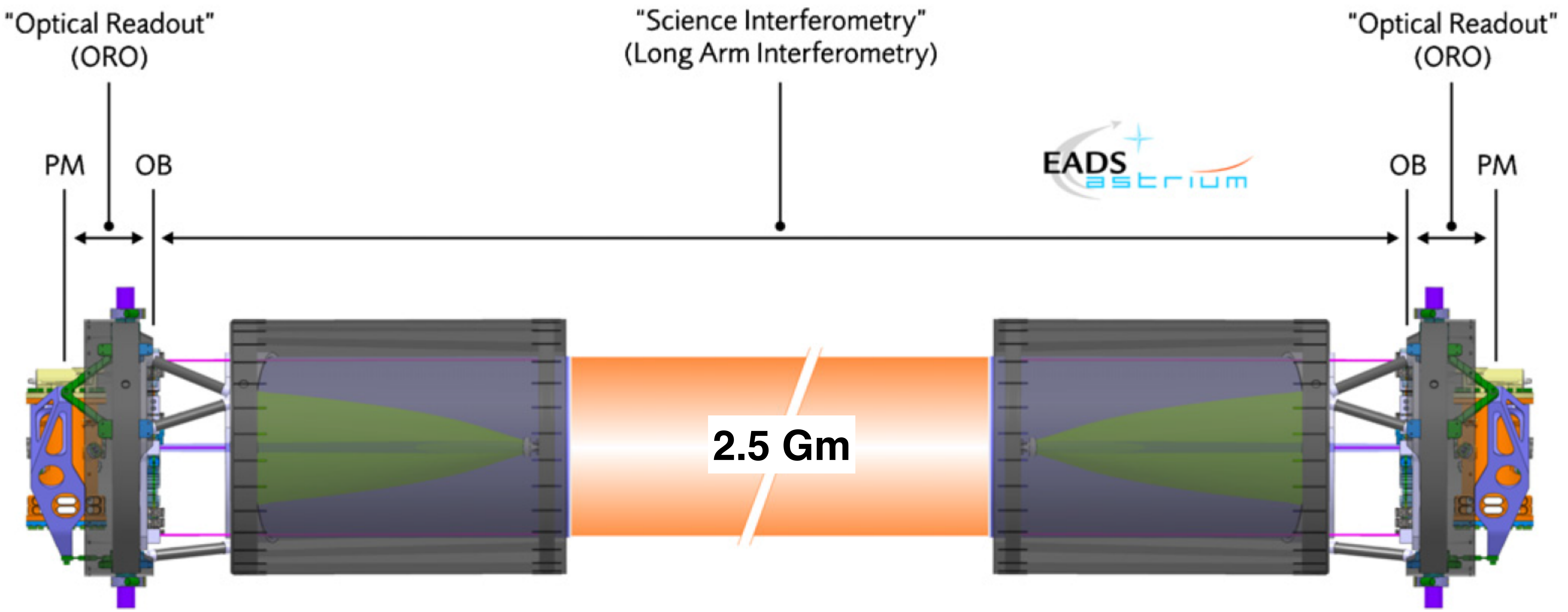
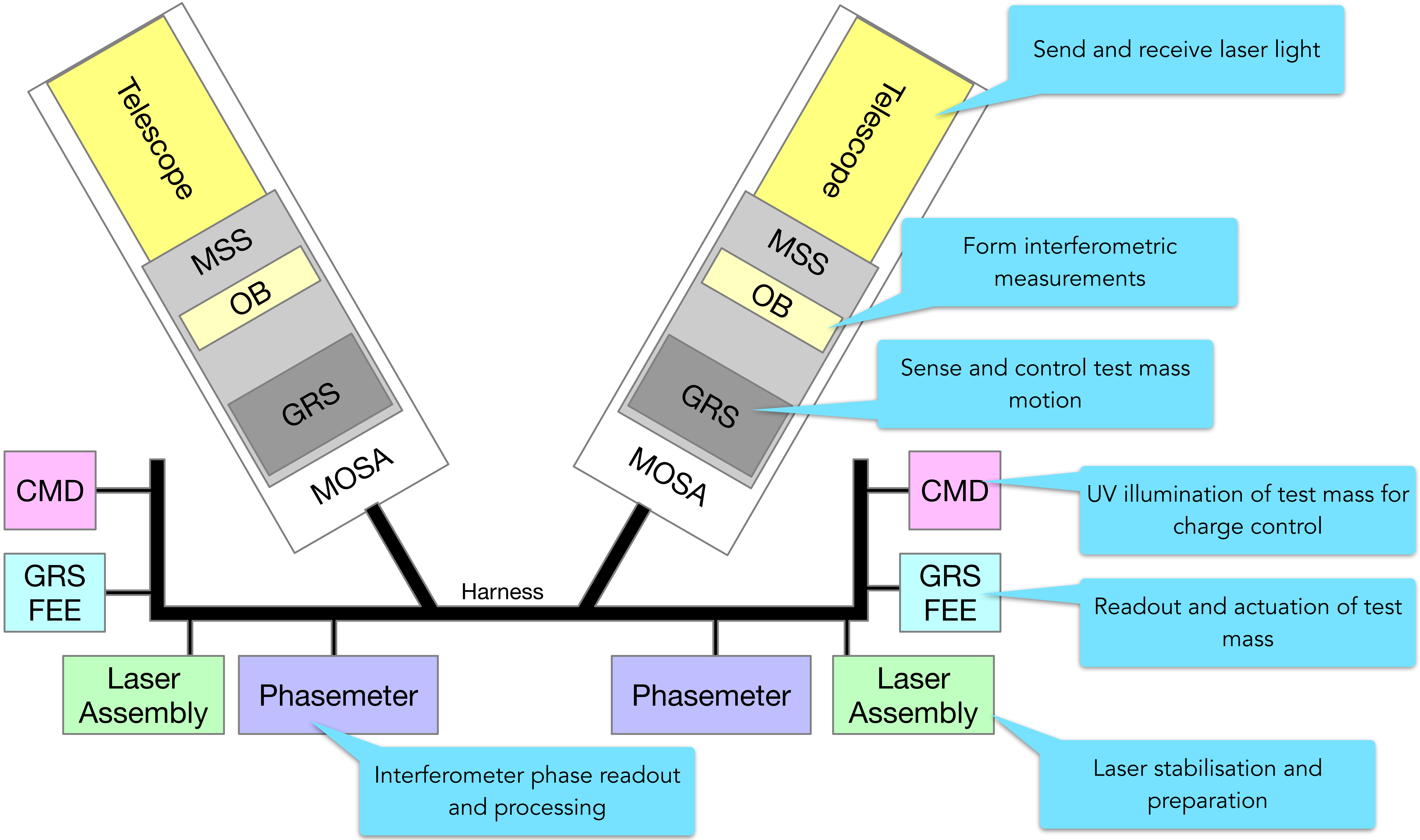


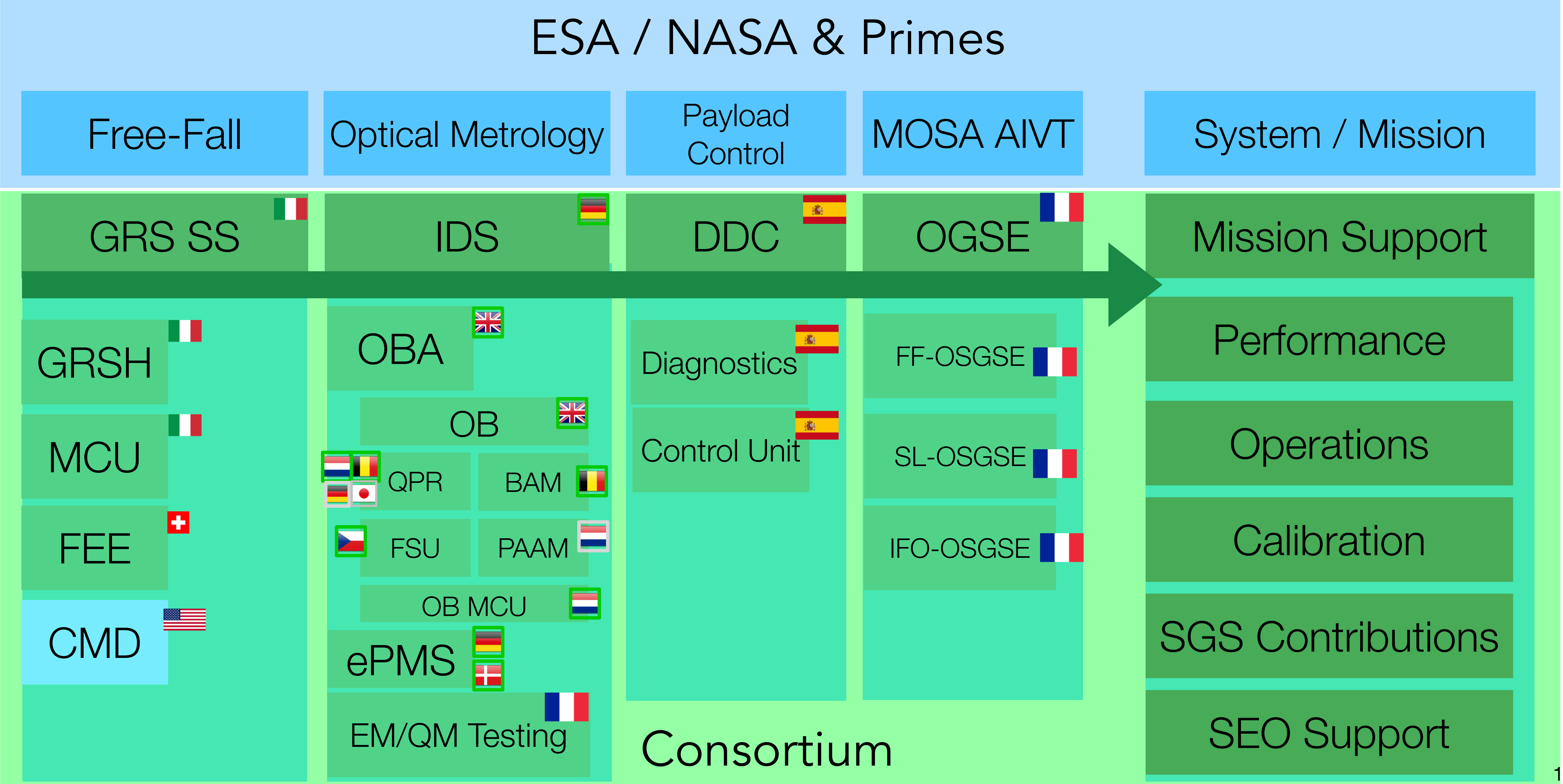
Testmass to Testmass interferometry split:

- TM to OB OB to OB OB to TM

LISA Interferometer Space Antenna

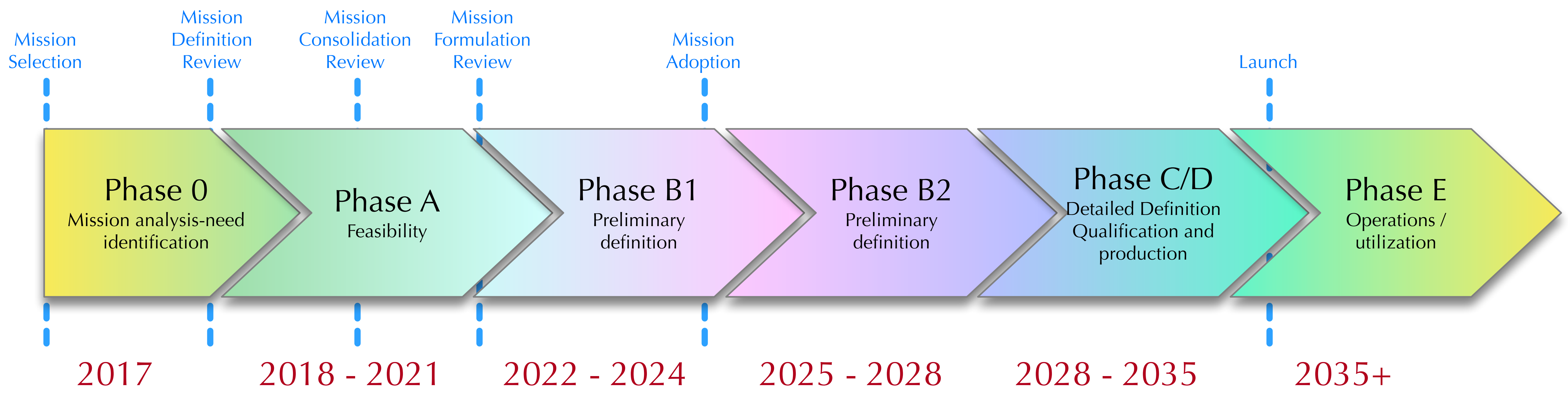


Proposed Consortium national contributions



Mission Status

- Passed Phase A Mission Formulation Review
  - Feasibility: development of a mission design that can fulfil the science objectives
- Started Phase B1
  - Focus on establishing all the needed requirements and their interfaces
  - Confirming all responsibilities and plans for implementation phase
- Aiming for mission adoption end of 2023 or early 2024
- Launch in 2035



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