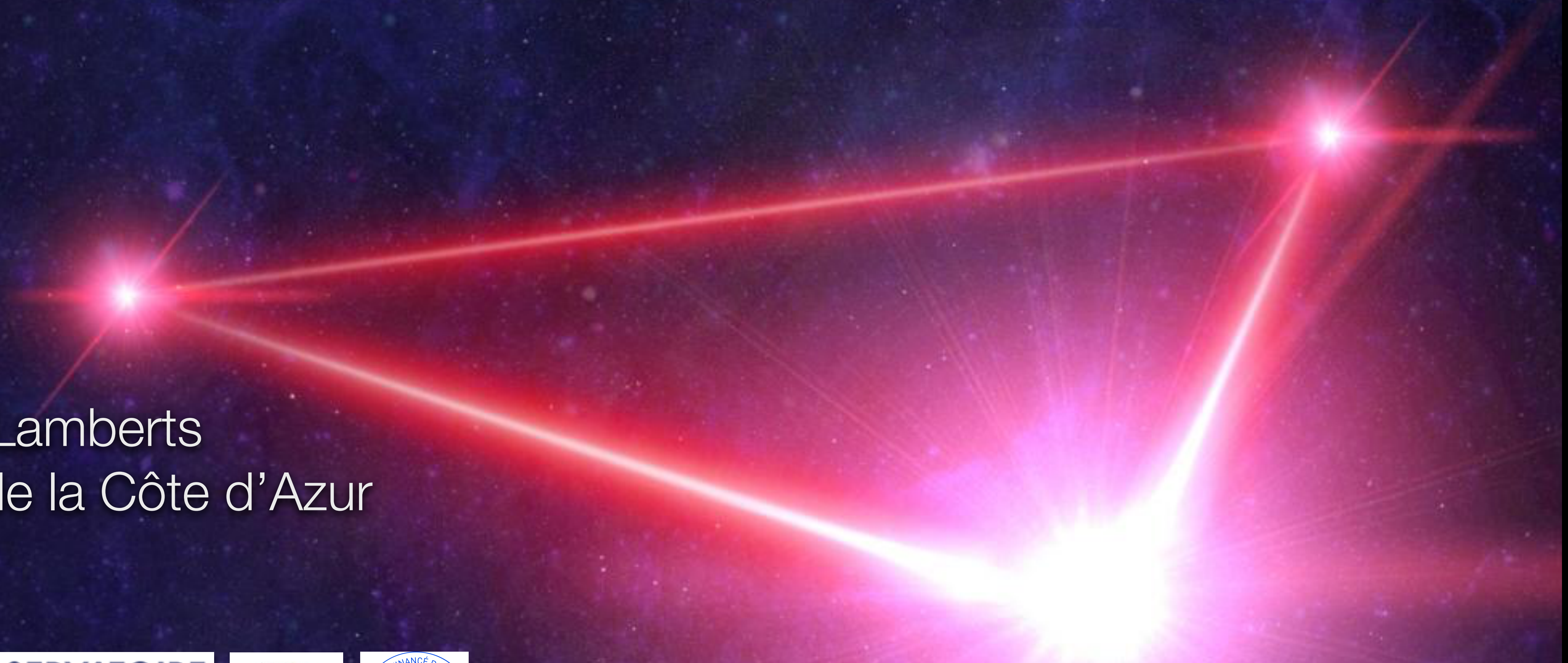
Laser Interferometer Space Antenna

Astrid Lamberts
Observatoire de la Côte d'Azur



NASA/JPL-Caltech/NASAEA/ESA/CXC/STScI/GSFCVS/S.Barke

LISA CONSORTIUM · OBSERVATOIRE DE LA CÔTE D'AZUR · UNIVERSITÉ CÔTE D'AZUR · cnrs · ANR

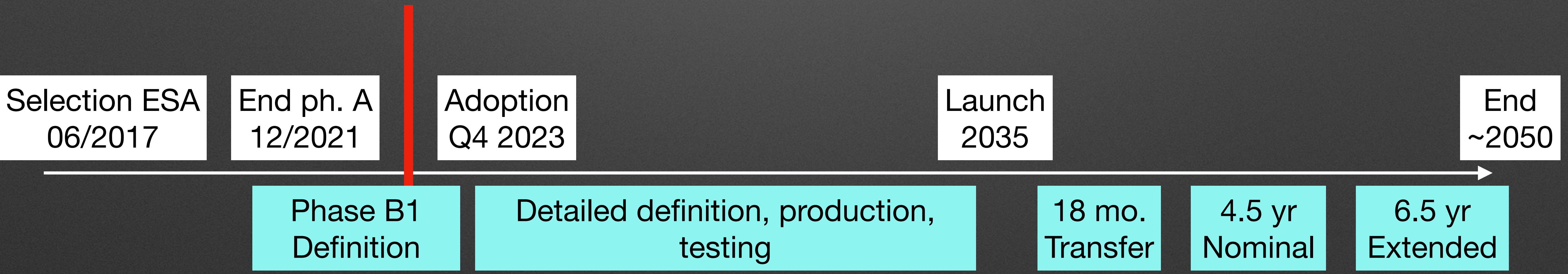
EUROPEAN SPACE AGENCY L3 MISSION

First ESA/NASA proposal in the 90's

Selected as flagship mission for the « Gravitational Universe » in 2017 (Cosmic Vision program), cost cap 1.3 Billion Euros

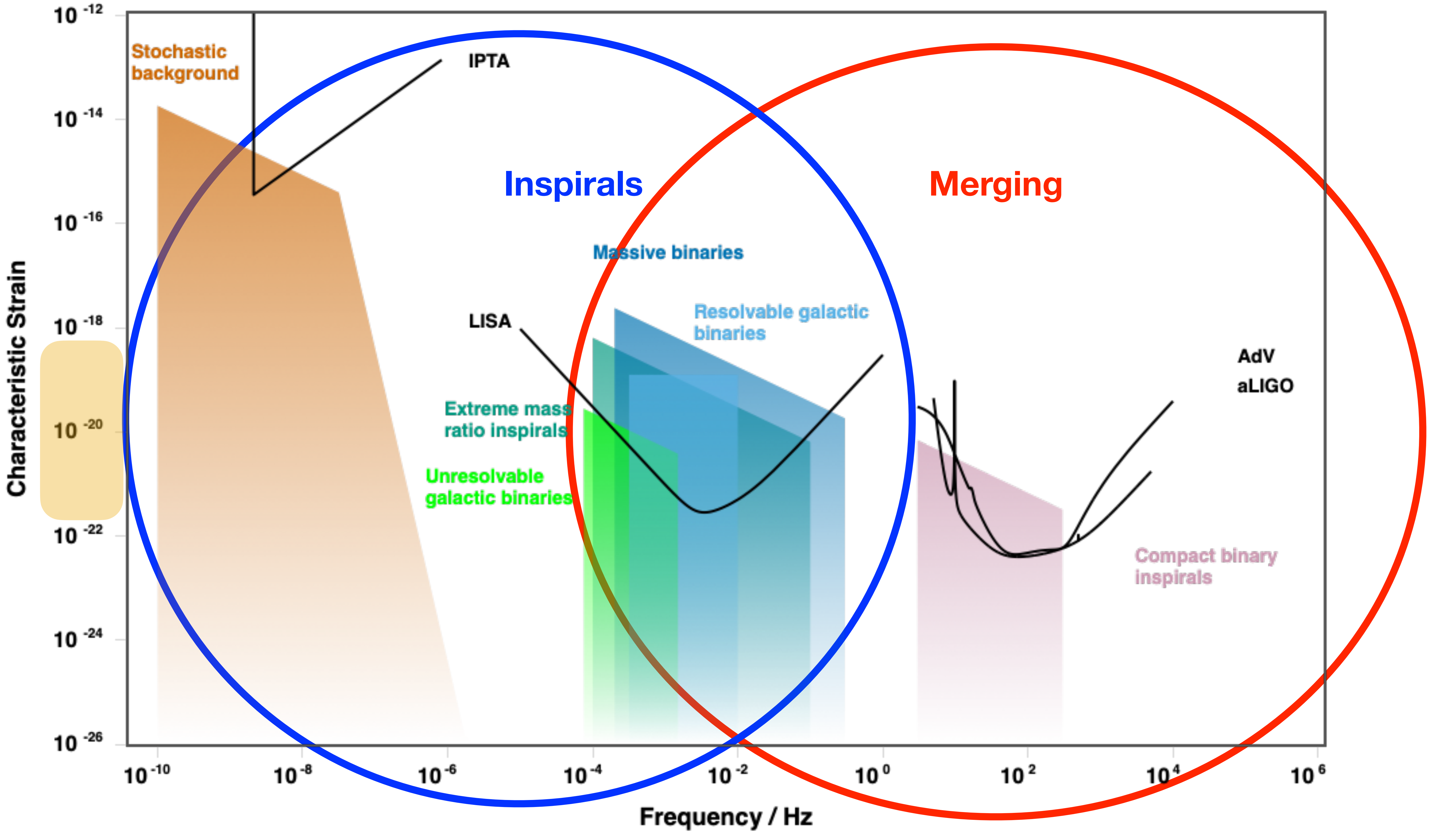
Expected launch mid-2030's

Adoption (initially) planned 2024 -> now 2023



Germany, France, Switzerland, Italy, UK, US, Belgium, Denmark, Spain, Finland, Hungary, Netherlands, Portugal, Romania, Sweden

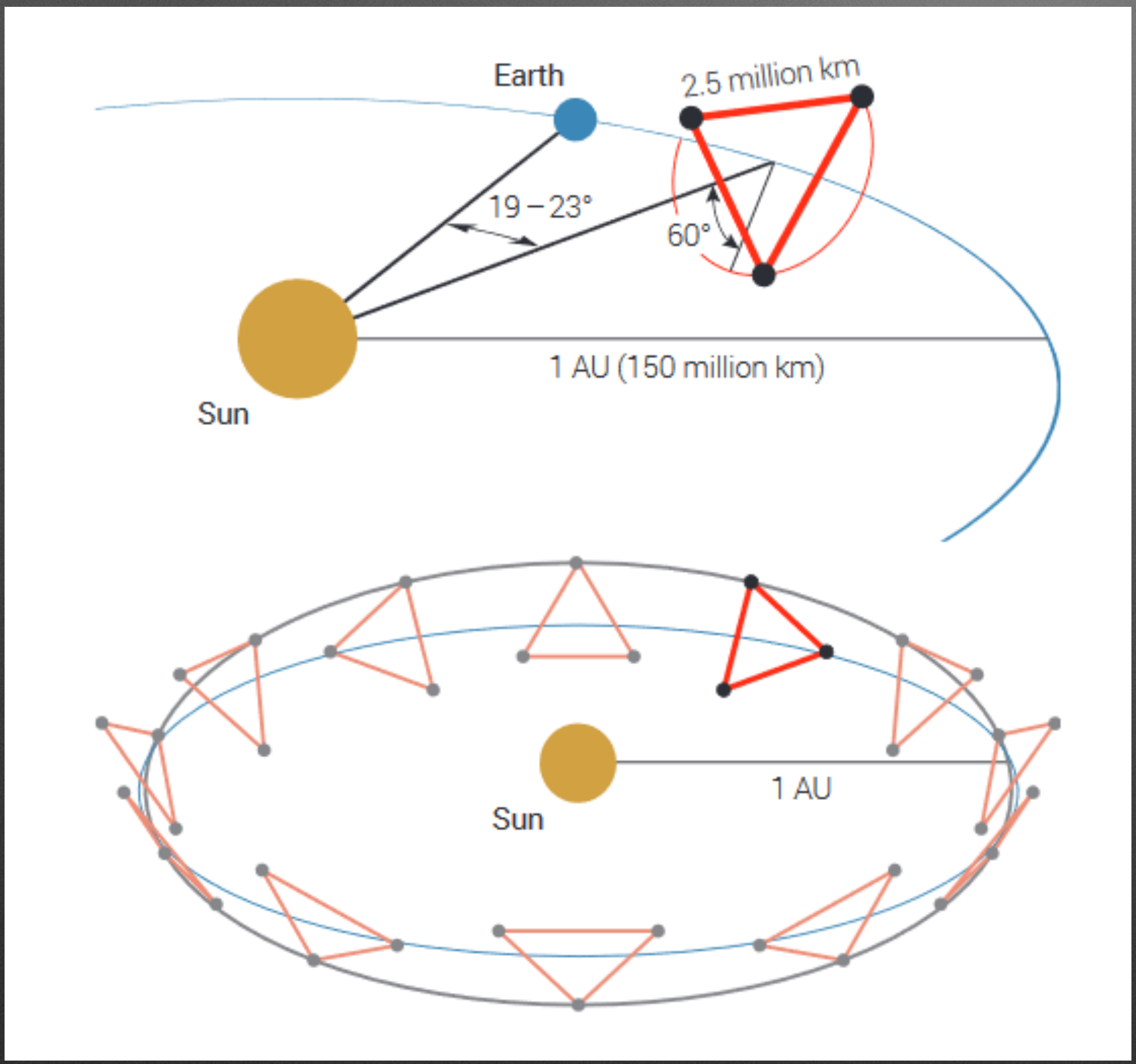
Frequencies of gravitational waves



$$f_{GW} = 2f_{orb}$$

$$A_{GW} \propto \frac{M_c^{5/3} f^{2/3}}{D}$$

THE LISA CONSTELLATION



3 spacecrafts 20 days behind the Earth

2.5 million km separation

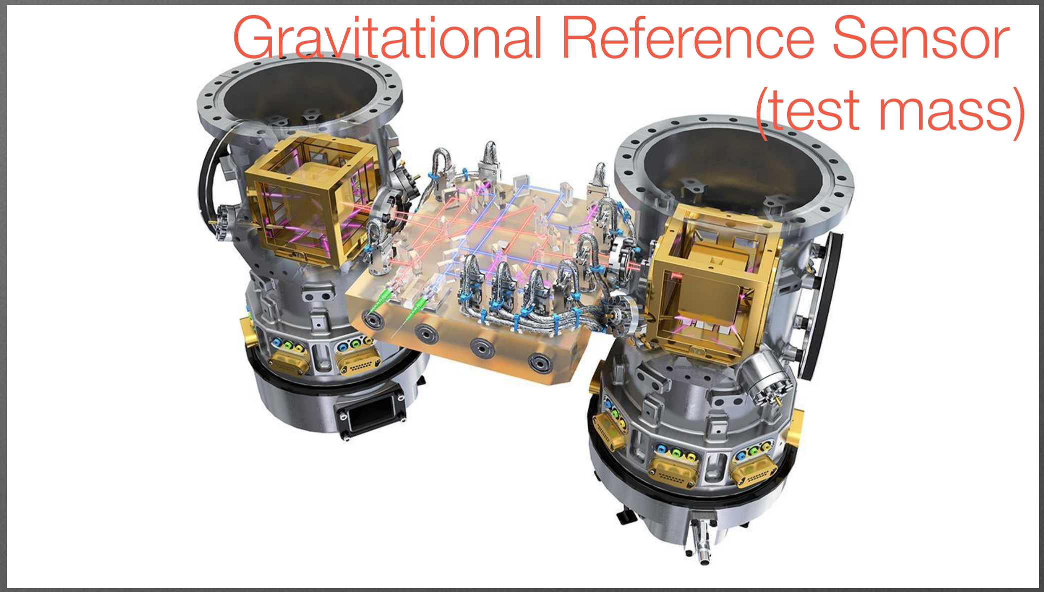
Distance measurements precision: 10^{-12} m

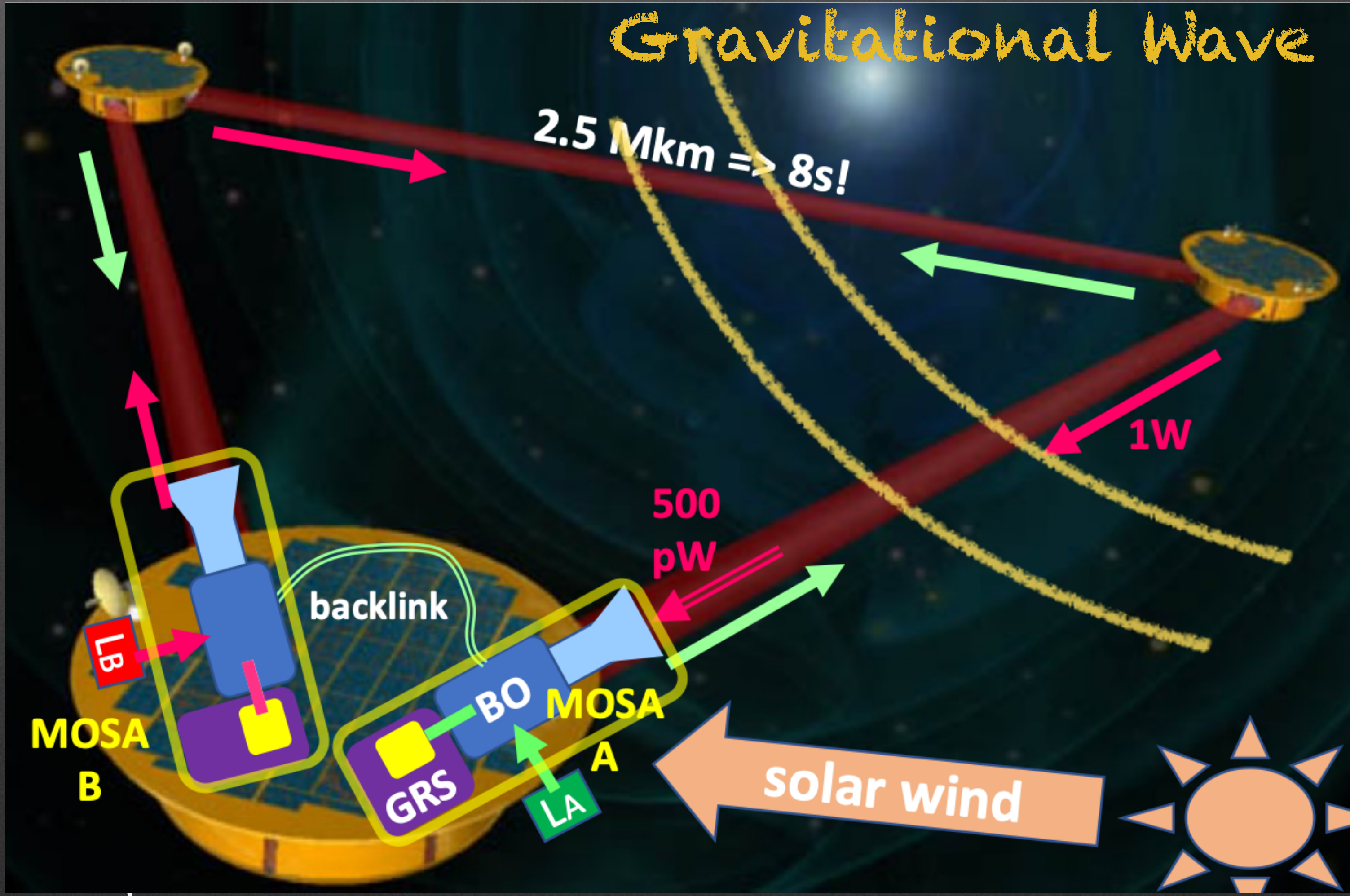
MEASUREMENT CONCEPT

Principle: measure distance variation between test masses

-> with laser interferometer

6 laser links: smart combination to extract GW signal (Time Delay Interferometry)

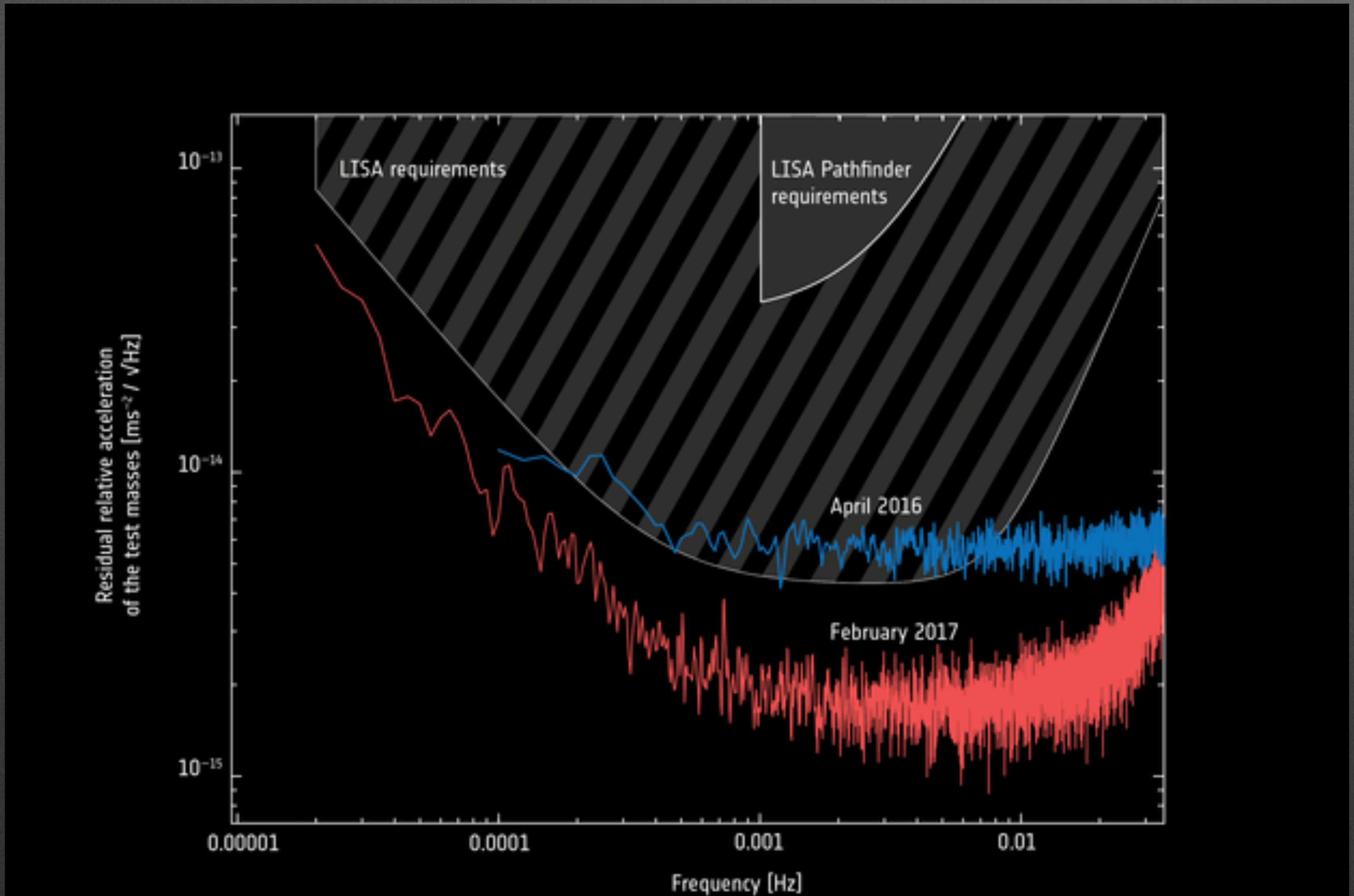




MOSA: Moving optical sub-assembly

WE KNOW IT WORKS !

LISA Pathfinder mission (2015) : following the path of the test masses works



LISA Pathfinder collaboration

LISA DATA ANALYSIS

Millions of superposed sources, very different from (current) ground-based detectors

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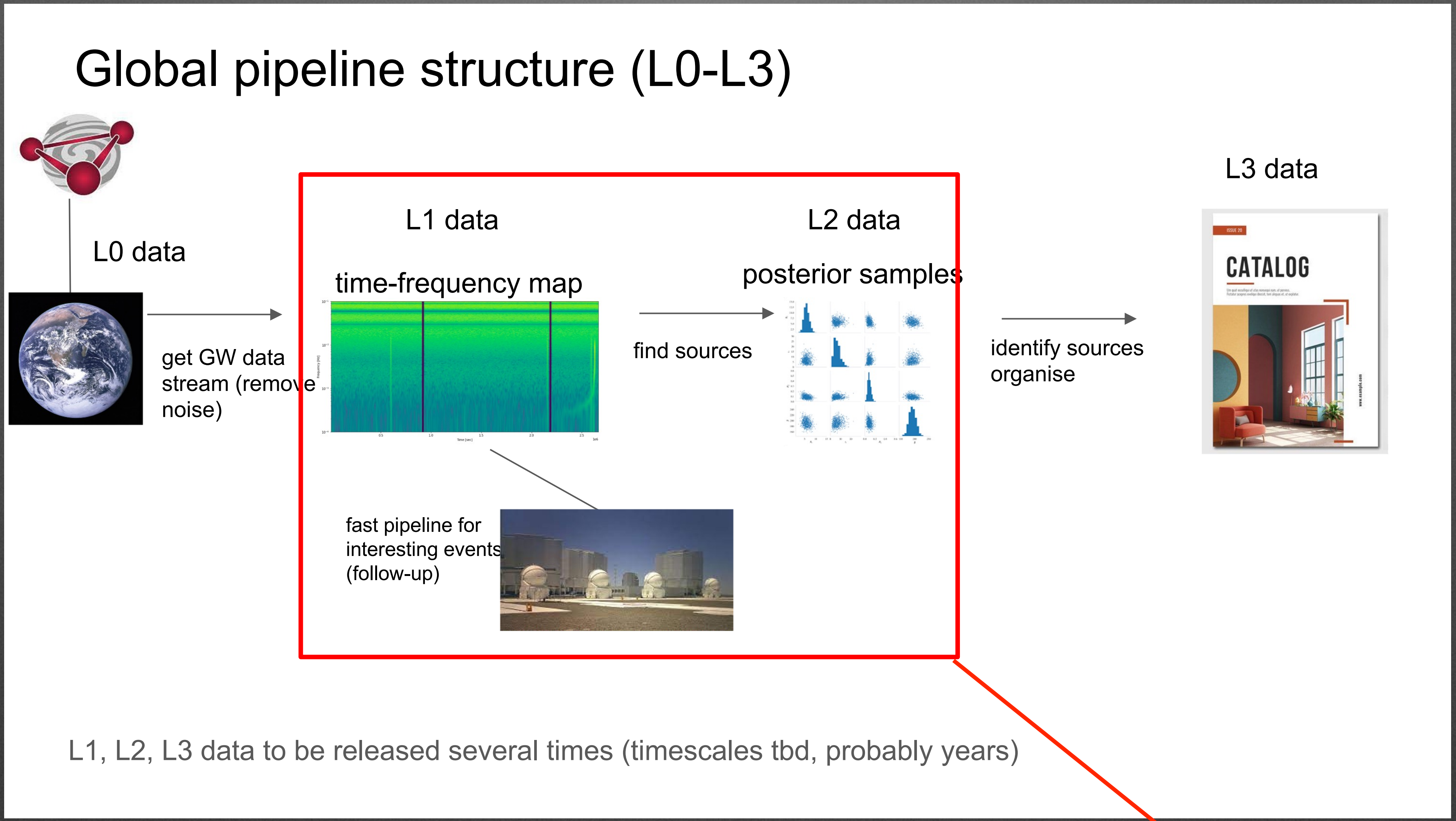
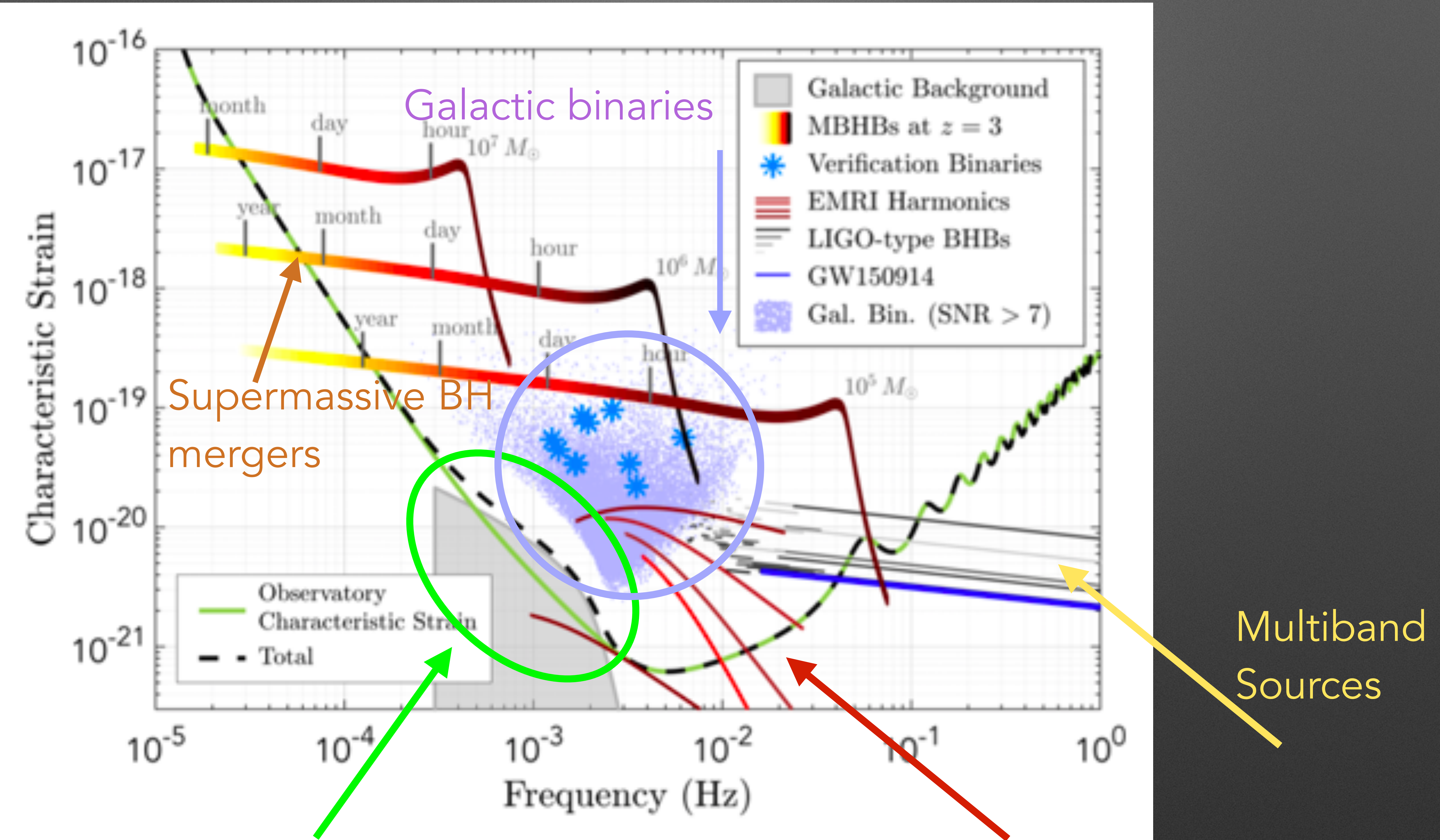


Global Bayesian Fit

Ongoing LISA Data Challenges

Coordinated by France

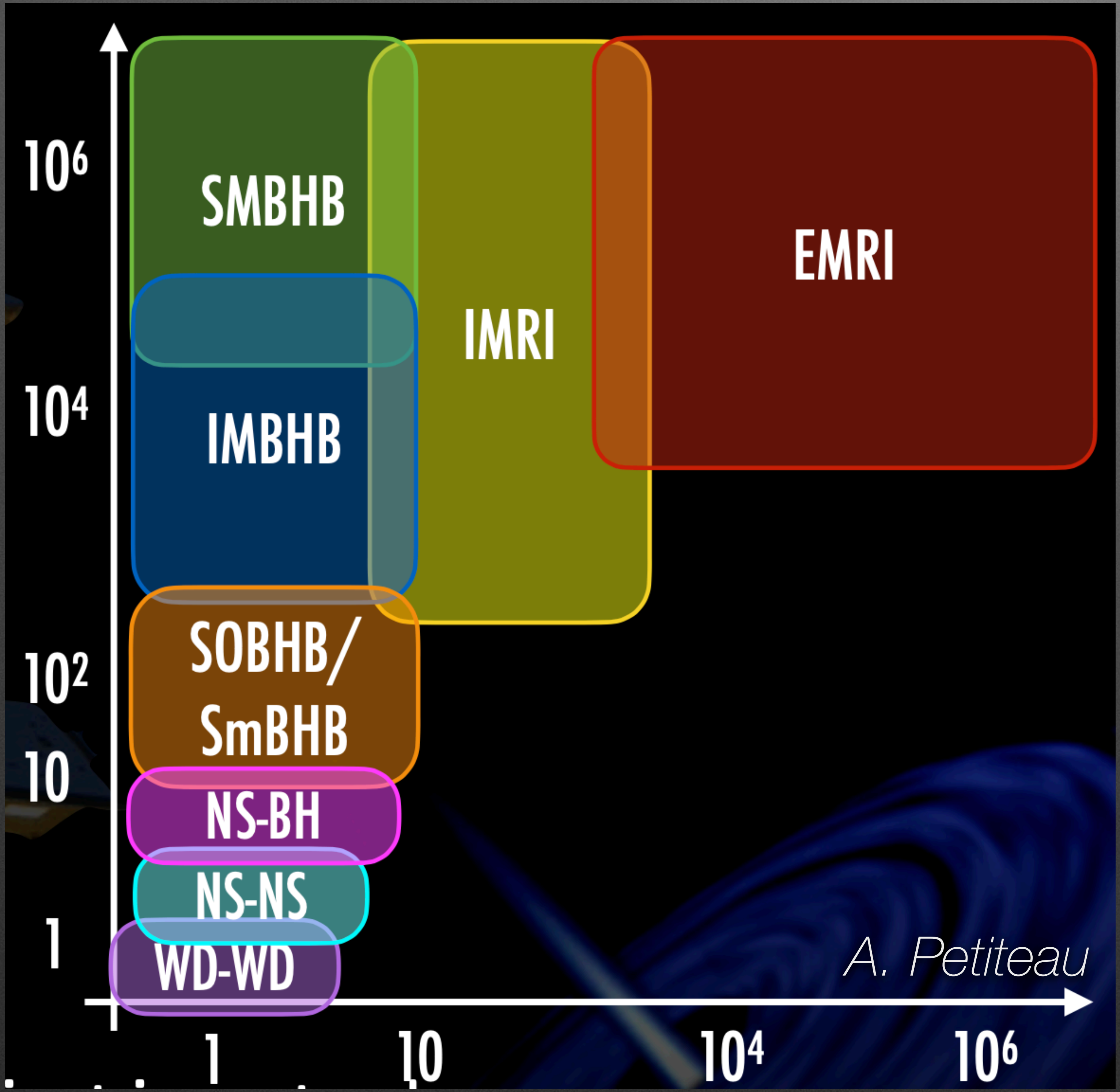
A WIDE VARIETY OF SOURCES



Unresolved sources:
Confusion noise

Extreme Mass Ratio Inspirals

A VERY WIDE RANGE OF COMPACT BINARIES



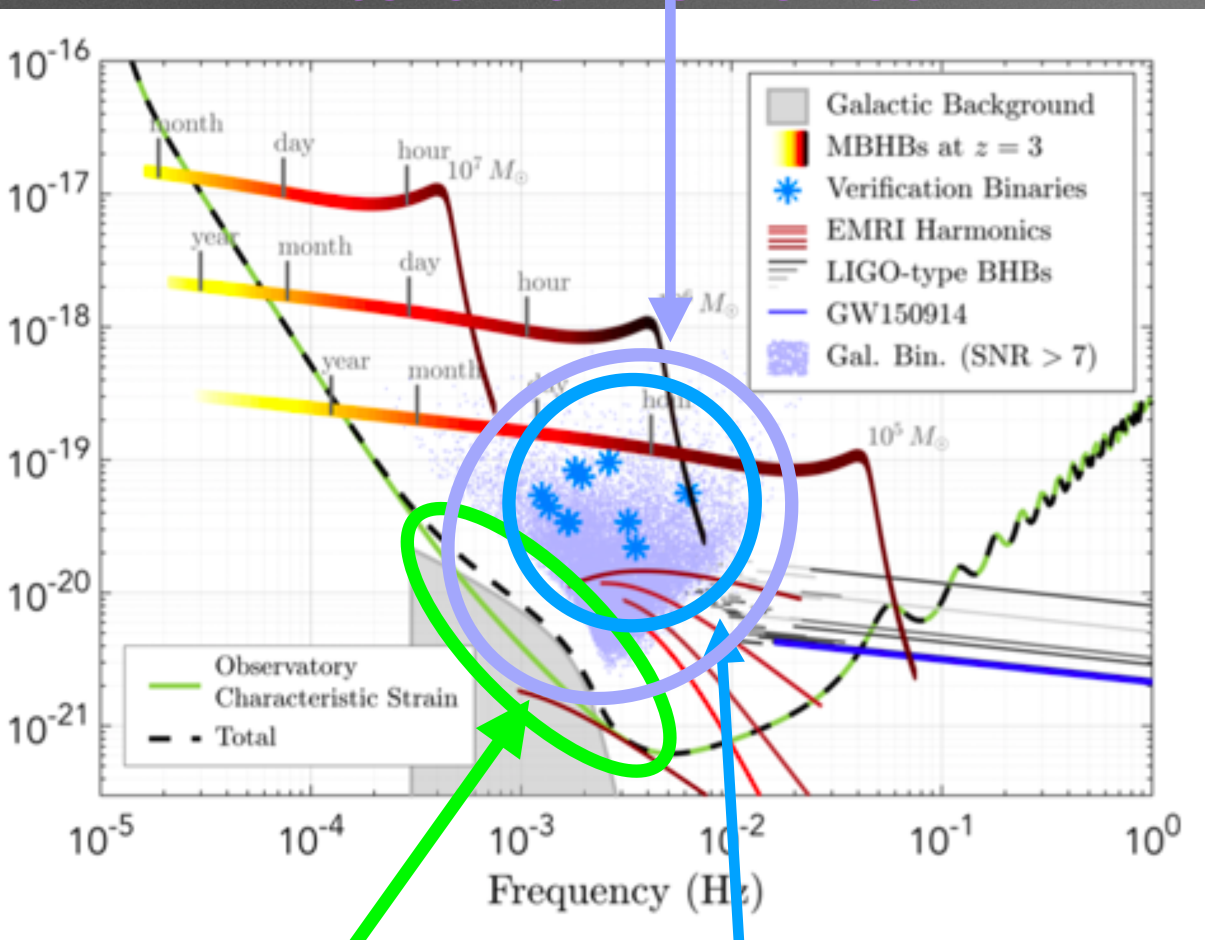
LISA SCIENCE OBJECTIVES

Astrophysics **Fundamental Physics** **Cosmology**

- SO1: Study the formation and evolution of compact binaries in the Milky Way
- SO2: Trace the origin, growth and merger history of massive black holes across cosmic ages
- S03: Probe the dynamics of dense nuclear clusters using EMRIs
- S04: Understand the astrophysics of stellar origin black holes
- SO5: Explore the fundamental nature of gravity and black holes
- SO6: Probe the rate of expansion of the Universe
- SO7:Understand stochastic GW backgrounds and their implications for the early Universe and TeV-scale particle physics
- SO8: Search for GW bursts and unforeseen sources

GALACTIC SOURCES

White dwarf binaires



Verification binaries

Unresolved sources: Confusion noise

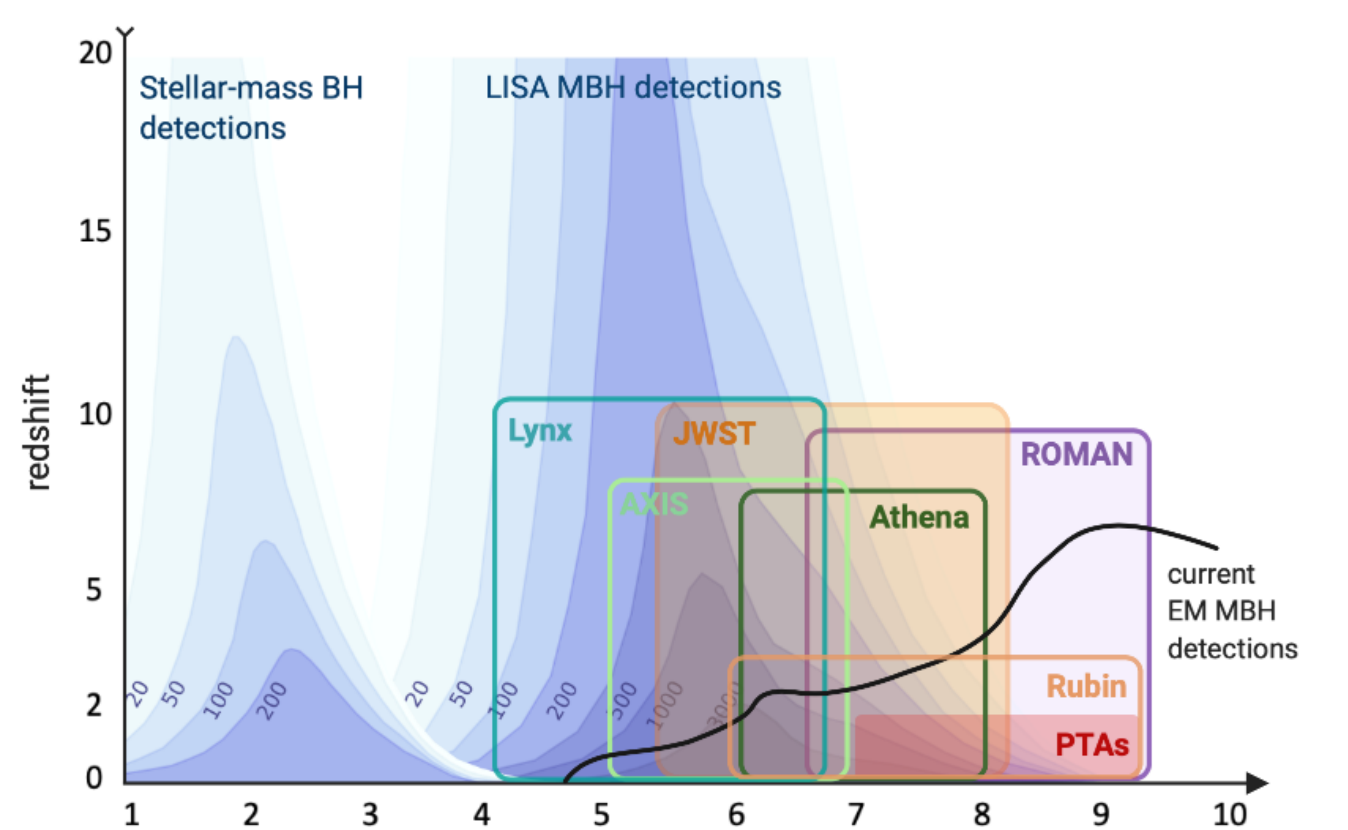
Tracing stellar remnants in the Milky Way

~ O 10^4 resolved white dwarf binaries -> guaranteed sources

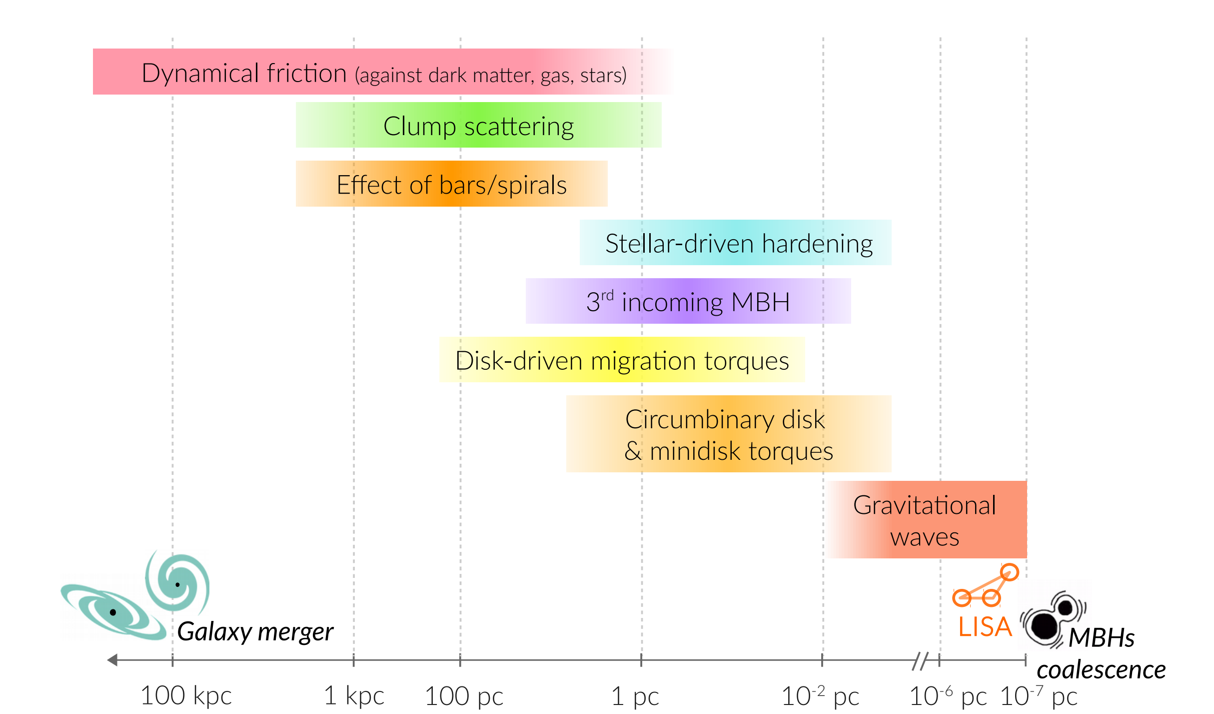
Fraction with mass measurements And/or « good » sky localisation -> multiomessenger sources

Some binaries with neutron stars, black holes, and/or « living stars », but will be hard to identify

SUPERMASSIVE BLACK HOLES



LISA Astrophysics WG



LISA Astrophysics WG

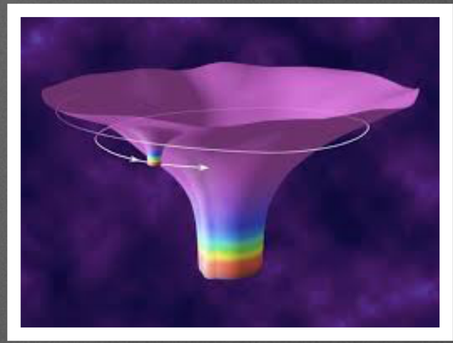
Understand formation and growth of supermassive black holes over cosmic history

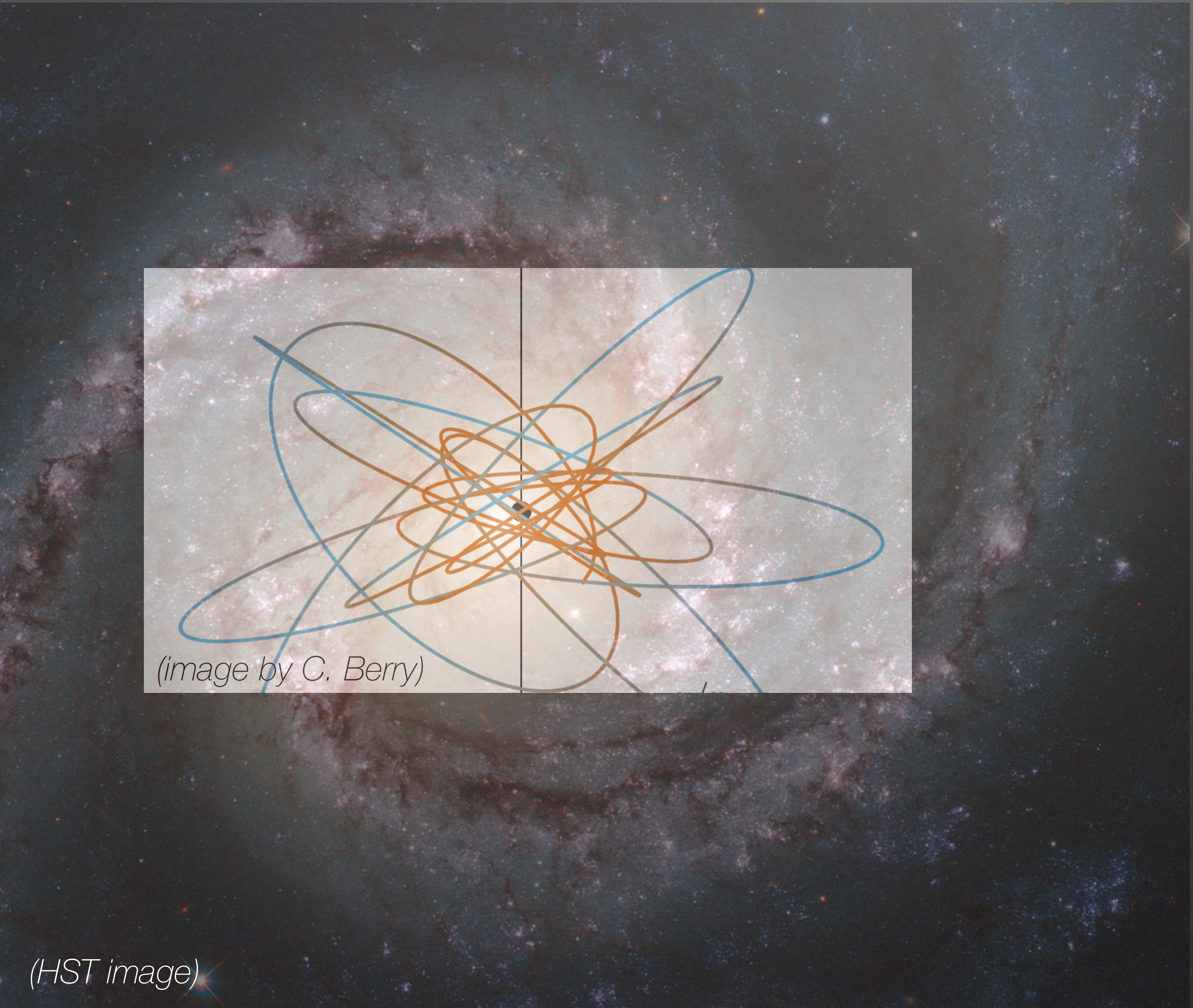
Inspiral (up to months before), merger and bringdown

Likely multi messenger sources-> low-latency EM follow-up

Major uncertainties: Event Rate hard to predict: 10-100 year

EXTREME MASS RATIO INSPIRALS





(image by C. Berry)

(HST image)

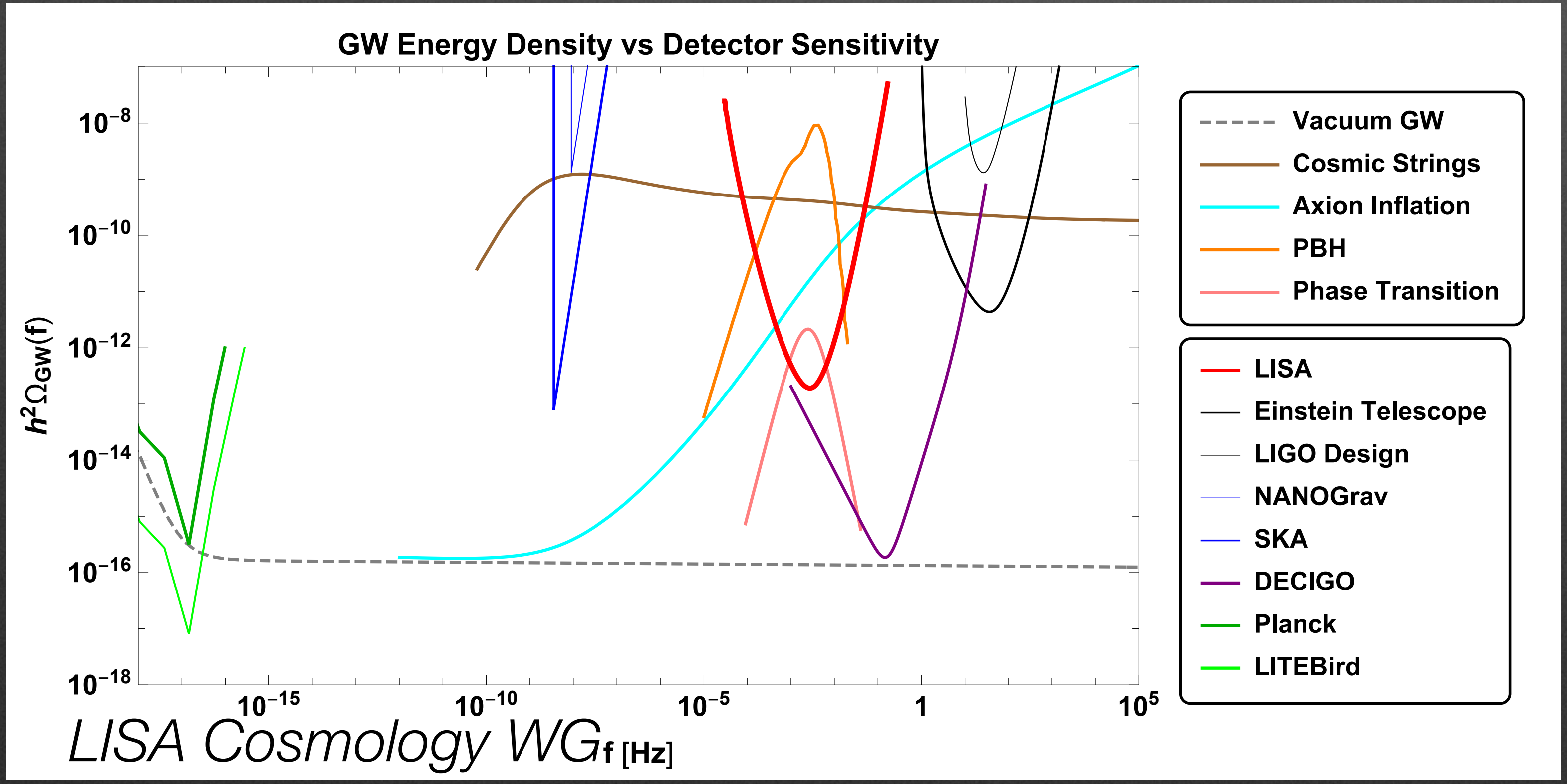
Stellar black hole around supermassive black hole
-> probe gravity under extreme conditions

Very complex sources in terms of waveforms

Very uncertain rates (few/yr -> 100s /yr)

COSMOLOGICAL BACKGROUND(S)

Probe regions beyond EM and neutrinos
Connect to constraints from PTA and kHz detectors
Need to disentangle from astro background/foreground



Recent White Papers & extra information

- Living Reviews in Relativity
- Astrophysics with the Laser Interferometer Space Antenna (Amaro-Seoane+22)
- Cocmology with the … (Auclair+22)
- New Horizons for fundamental Physics with LISA (Arun+22)
- Waveforms (in prep.)
- Data Challenge (in prep.)
- https://lisa-ldc.lal.in2p3.fr/challenge2a
- elisascience.org
- Consortium with Full Members and Associate Members

GRAVITATIONAL WAVE OBSERVATIONS IN SPACE

LISA: ESA L3 mission
Expected to launch in 2035, expected adoption next year

Opening of a new frequency window of GWs
Major impact in astrophysics, cosmology and fundamental physics

Main sources:
Supermassive black hole mergers at cosmological distances
White dwarf binary inspirals in the Milky Way
Extreme mass ratio inspirals
Foregrounds and background