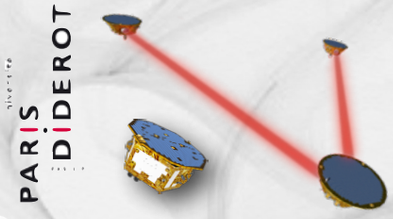
eLISA : vers un détecteur spatial d'ondes gravitationnelles

H. Halloin et al.
APC - CNRS/Université Paris Diderot



Orders of magnitude

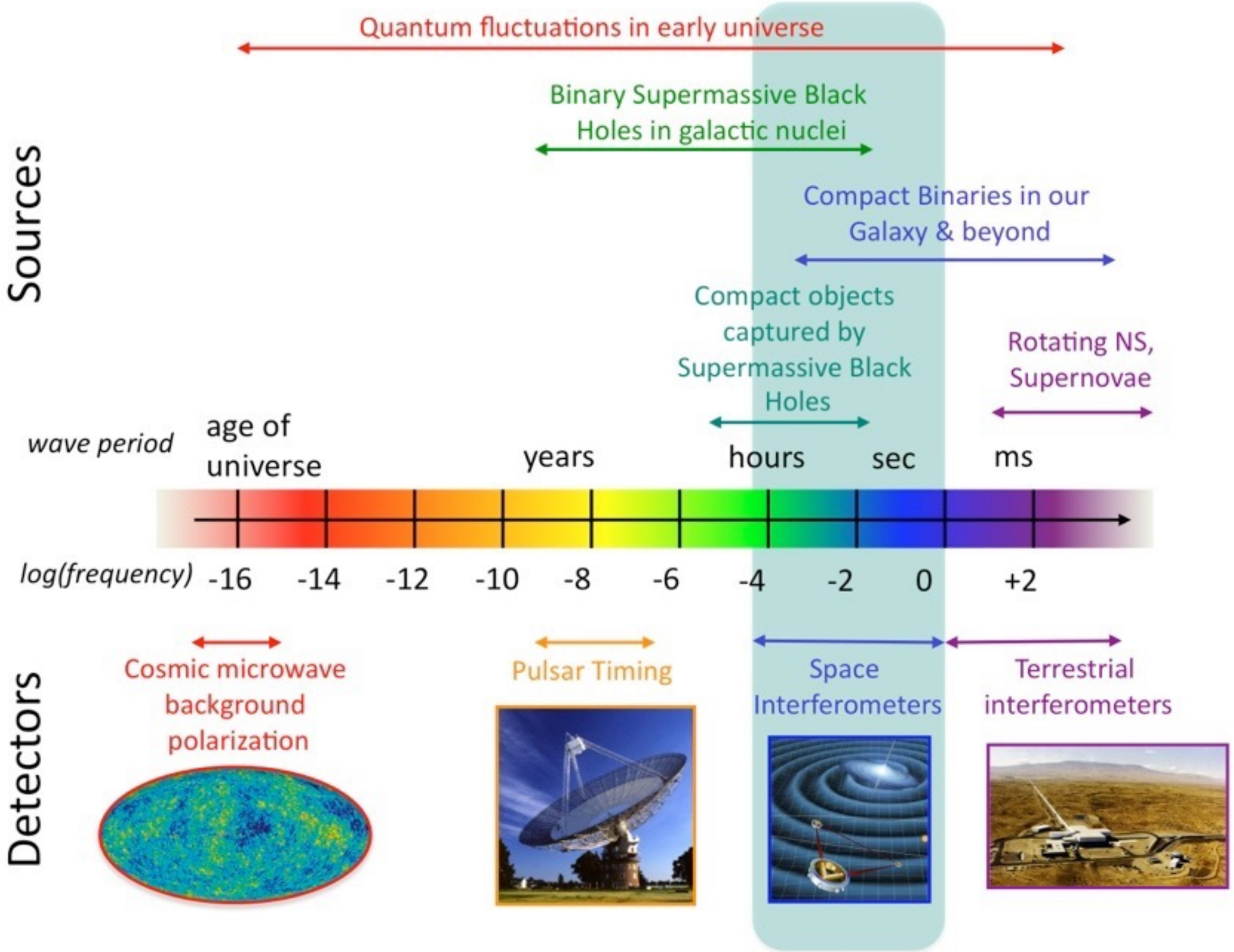
- Estimation of GW amplitude for a source of mass M, compacity κ, at a distance r :

$$h \approx 2\kappa \frac{GM}{rc^2} \approx 10 \text{ pm/Mkm } \frac{M}{M_{Soleil}} \frac{30 \text{ kal}}{r} \frac{\kappa}{0{,}001}$$

$$f \approx \sqrt{\frac{G\rho}{\pi}} \approx 2 \text{ Hz } \frac{M_{Soleil}}{M} \left(\frac{\kappa}{0{,}001} \right)^{3/2}$$

- ✓ Very massive and compact objects (massive BH binaries, SN, white dwarfs binaries, etc.) can produce significant signals
- ✓ Can be detected at very large distance (h scales as 1/r ...)
- ✓ The mass of the object drives the GW frequency

The Gravitational Wave Spectrum



eLISA

LISA

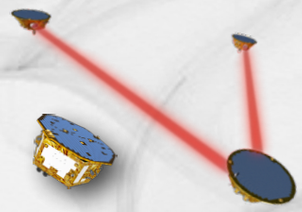
eLISA

eLISA = evolved Laser Interferometer Space Antenna

Space-borne, million-km arms, interferometer between free-floating test masses

No seismic disturbances

Long armlength : low GW frequencies (≈1mHz - 1 Hz), “high” antenna response



The path towards a space-borne GW detector

➡ 2013 : GW science theme selected for flight !

➡ Selected as the 3rd large mission of the ESA 'Cosmic Vision' program

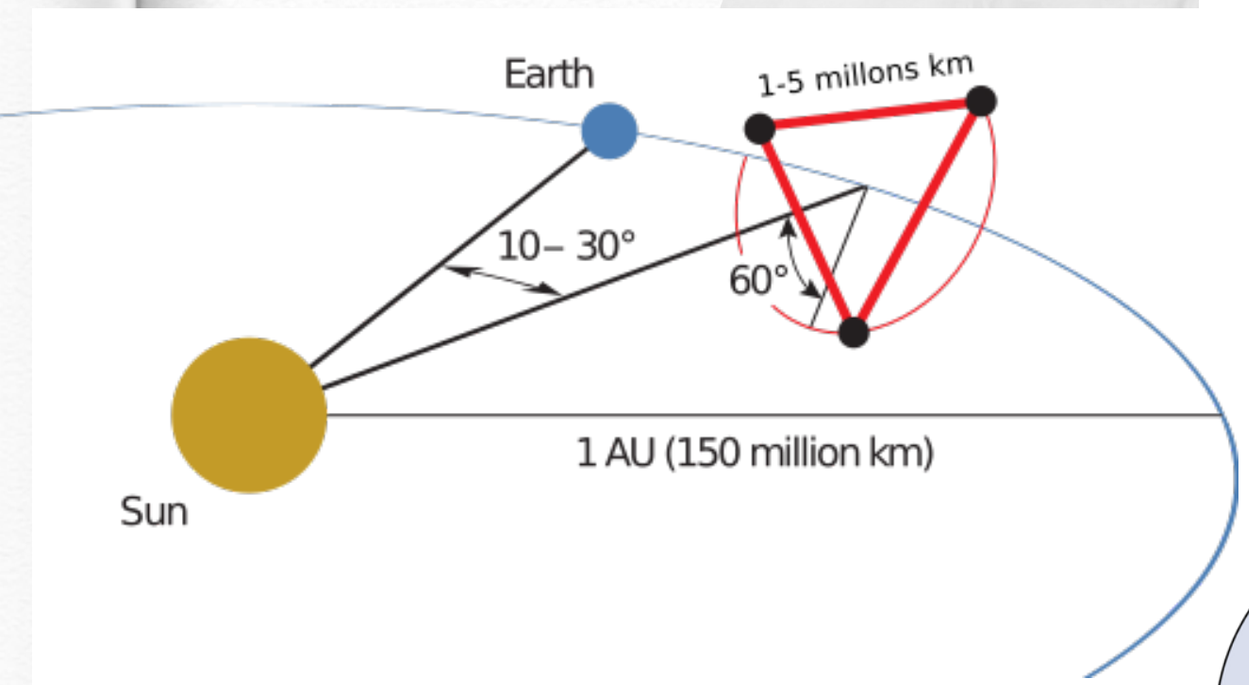
✓ Launch expected in 2030 - 2034

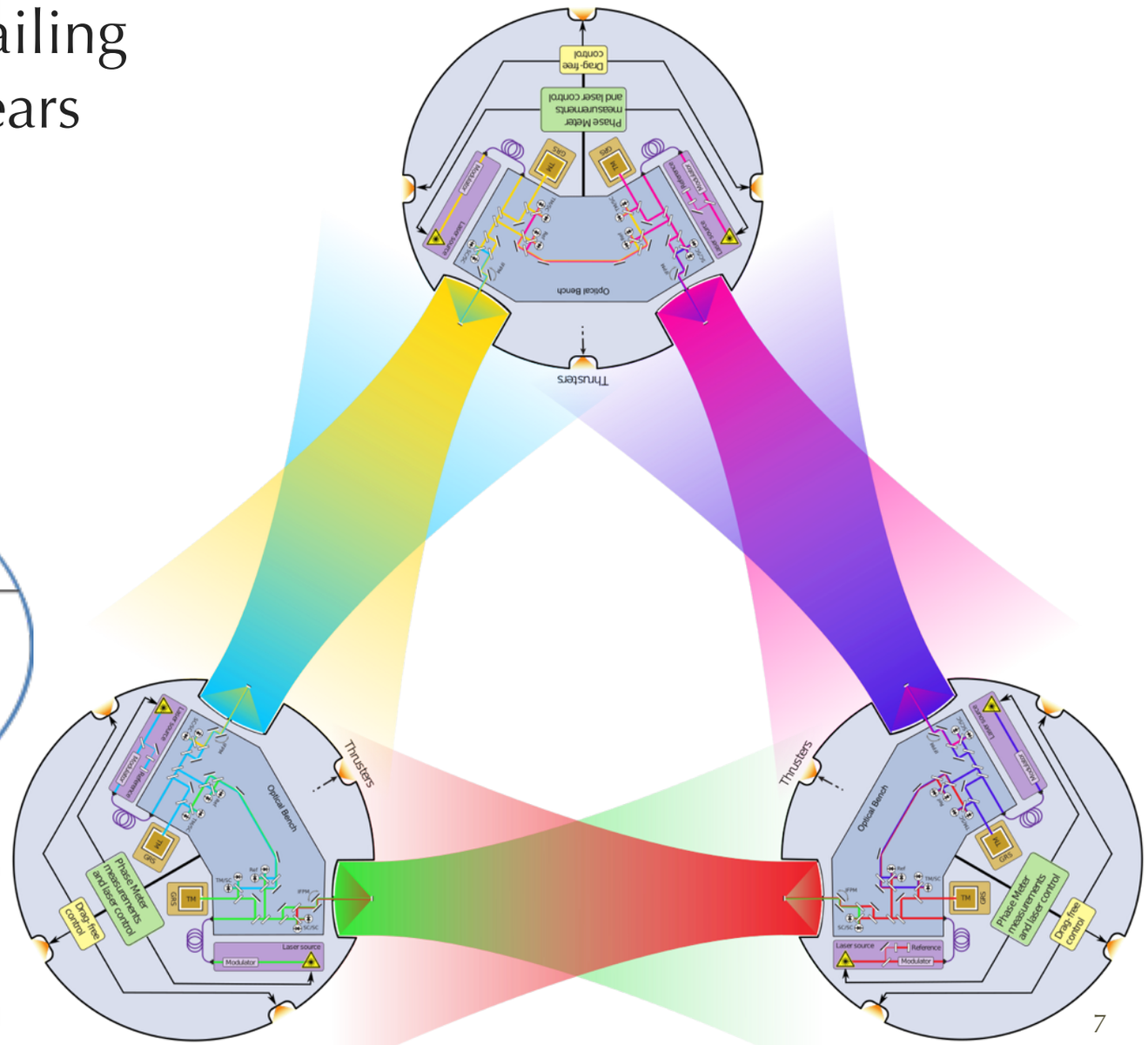
THE GRAVITATIONAL UNIVERSE

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

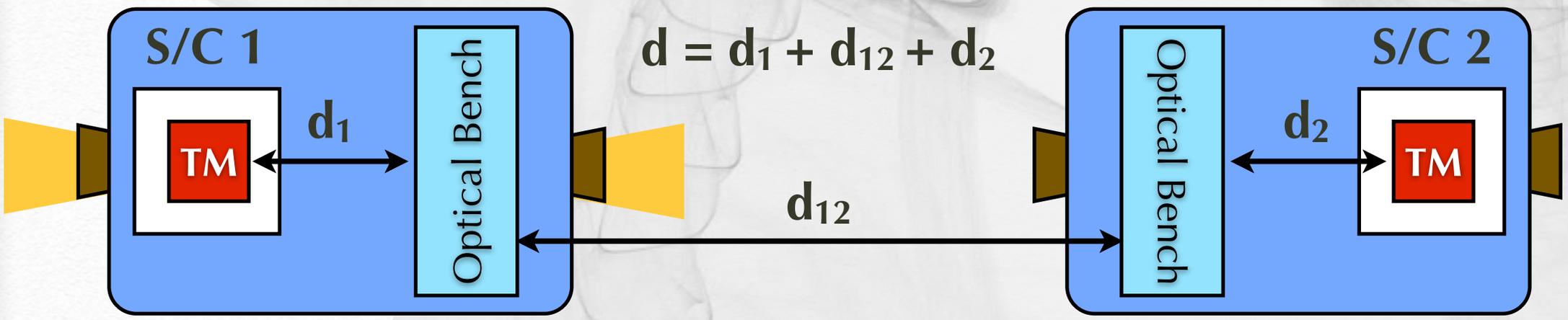
eLISA mission profile

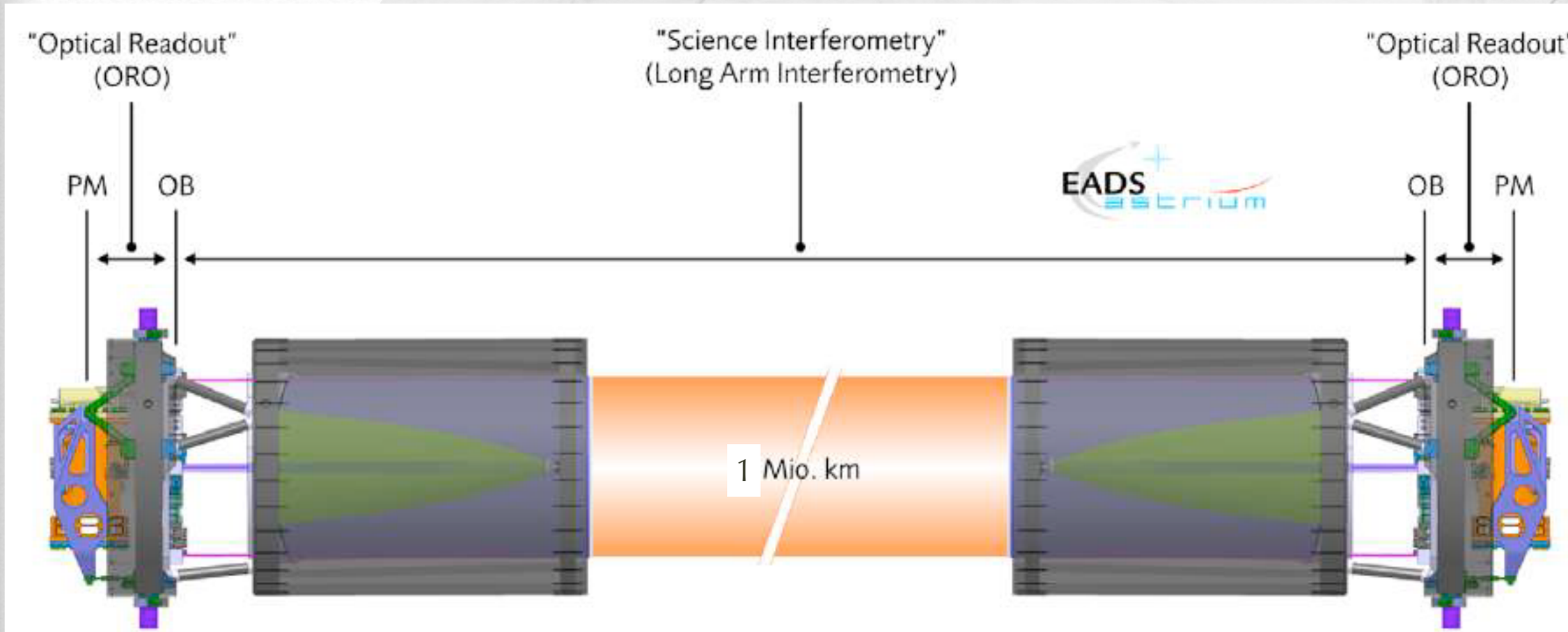
- Long arms interferometer
  - ✓ 1 to 5 Mkm arm length
  - ✓ 2 test masses / satellite
  - ✓ Earth-like orbit, 10° to 20° trailing
  - ✓ Mission duration : about 5 years



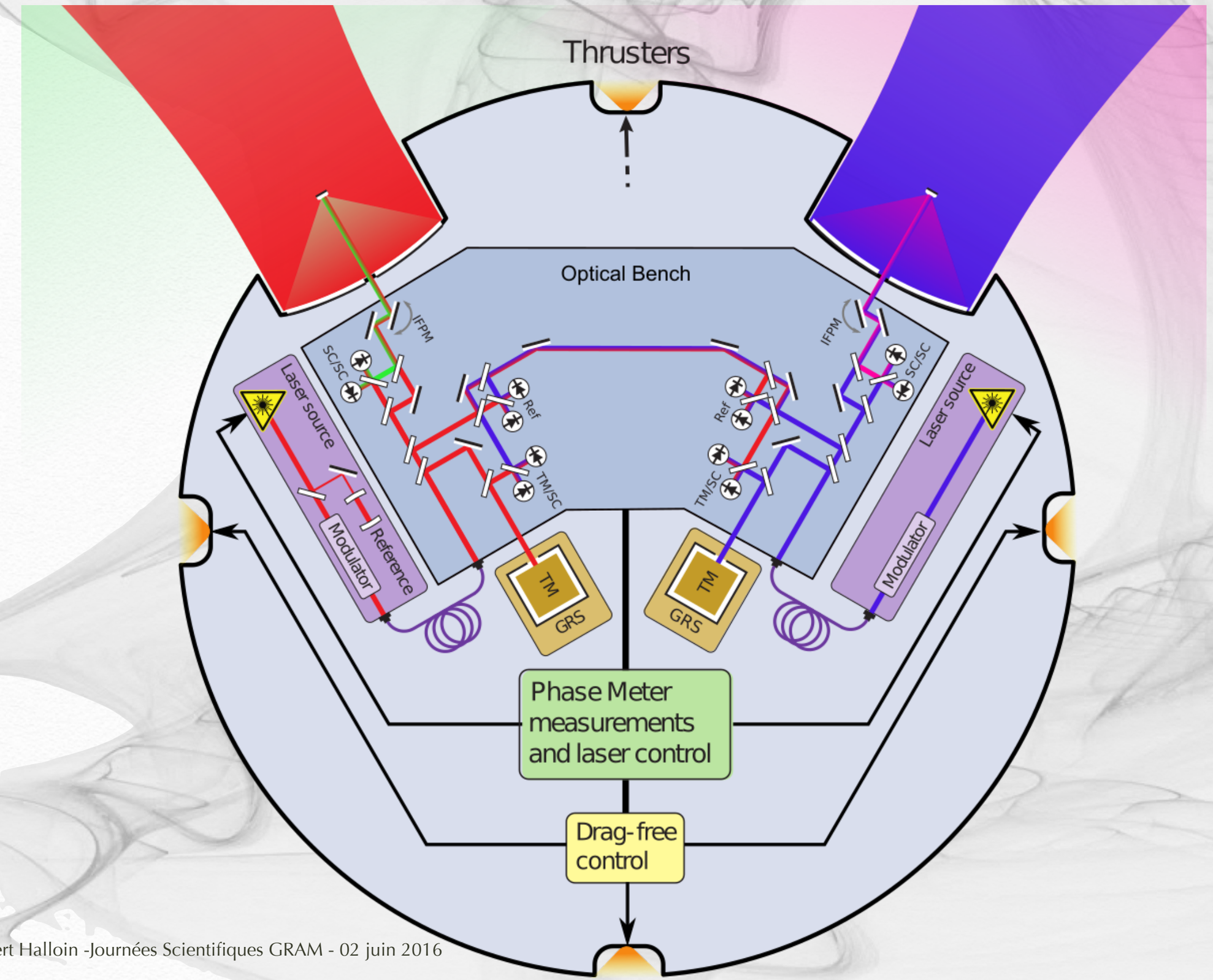


eLISA interferometric link



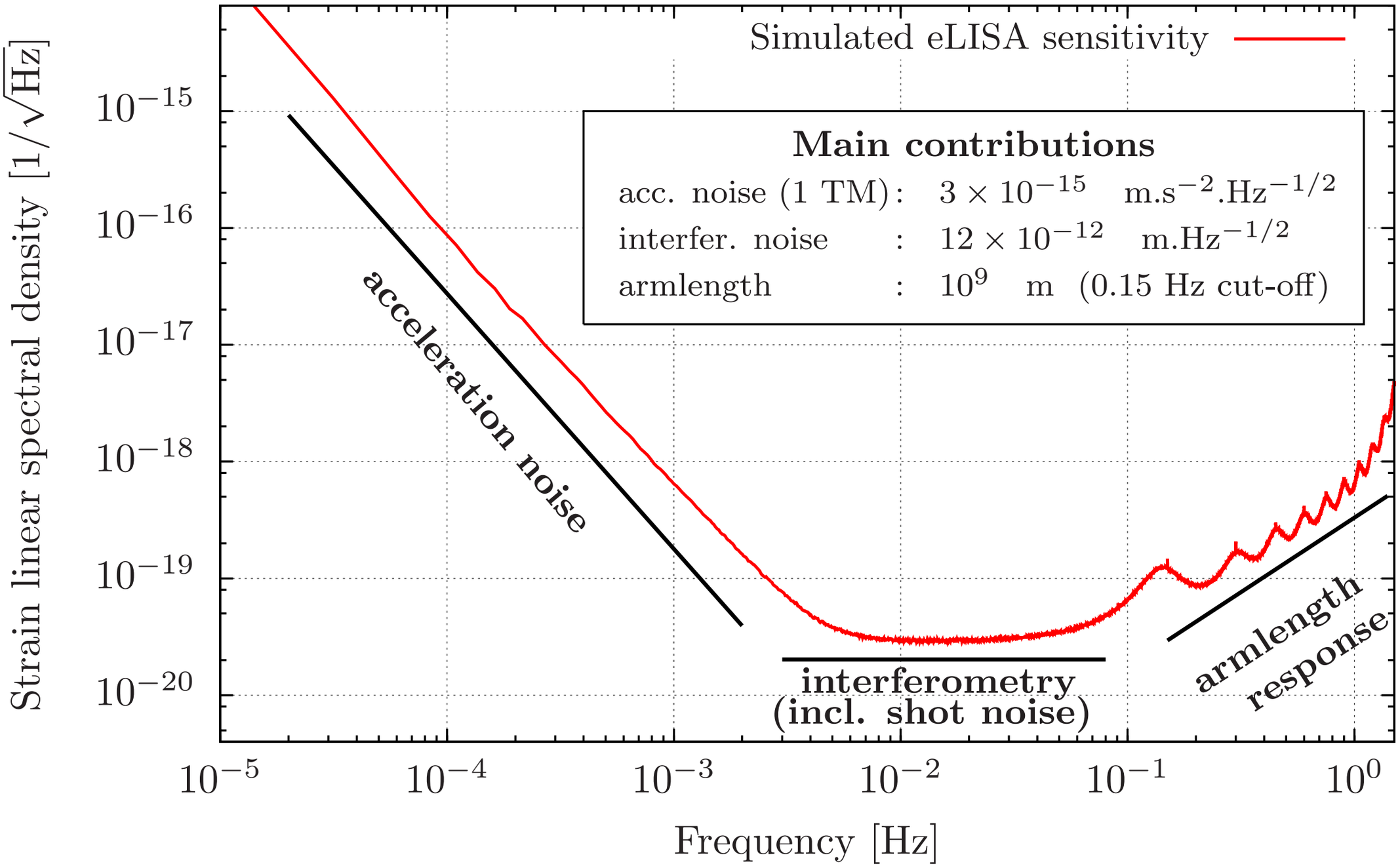


Scheme of one payload

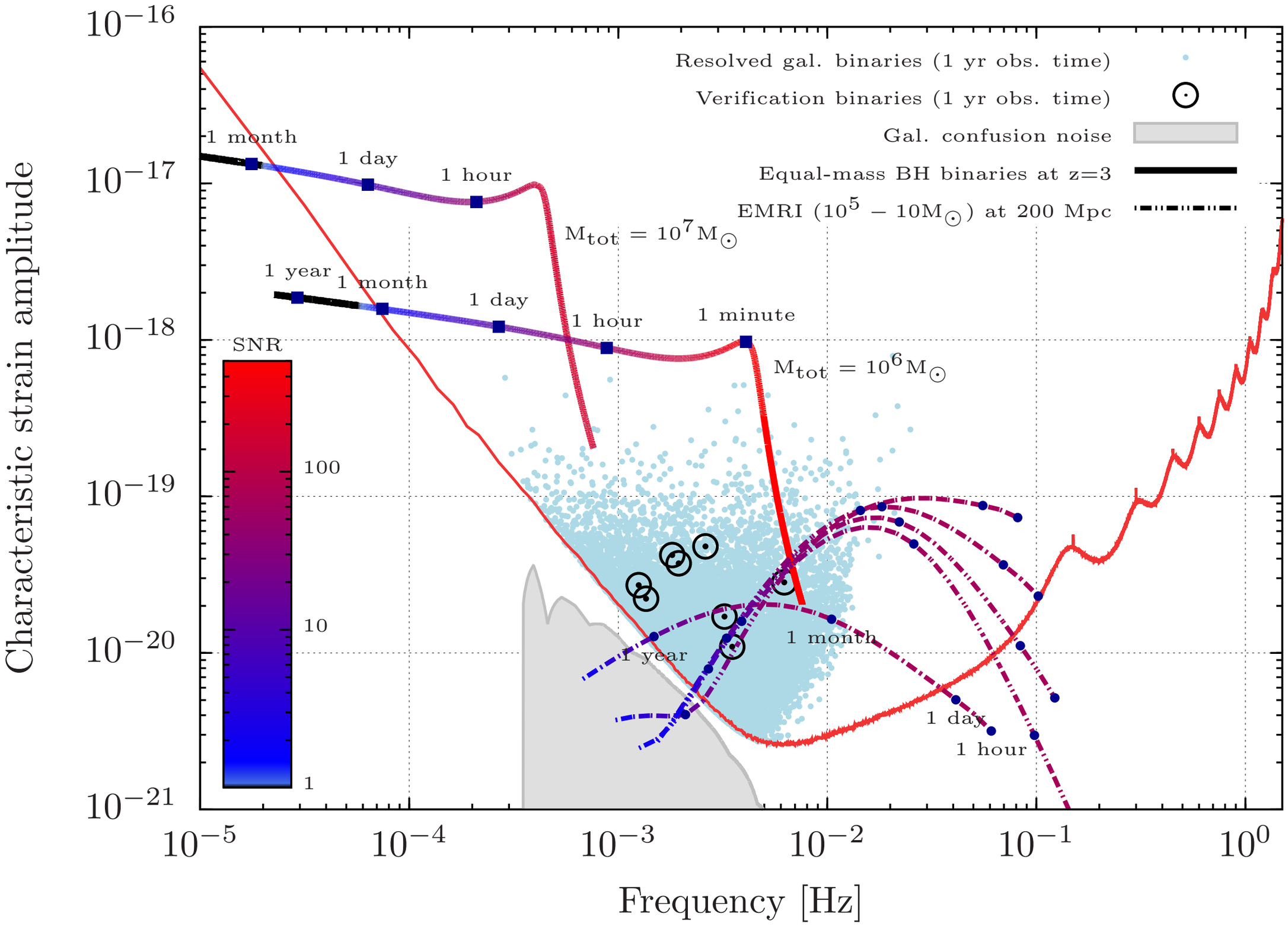


eLISA metrology performance

Time, sky and polarization averaged eLISA sensitivity
(linear spectral density)

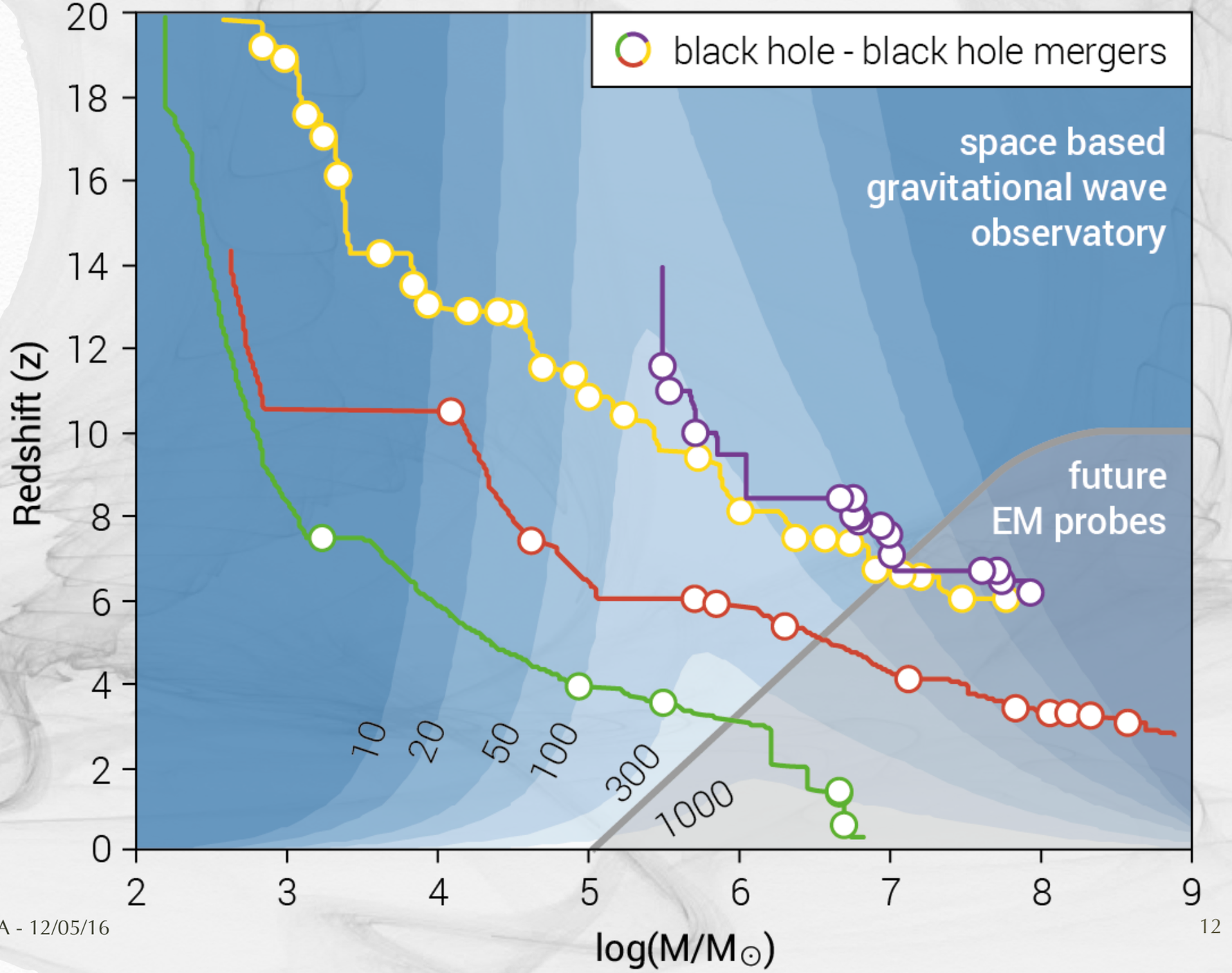


eLISA Sensitivity

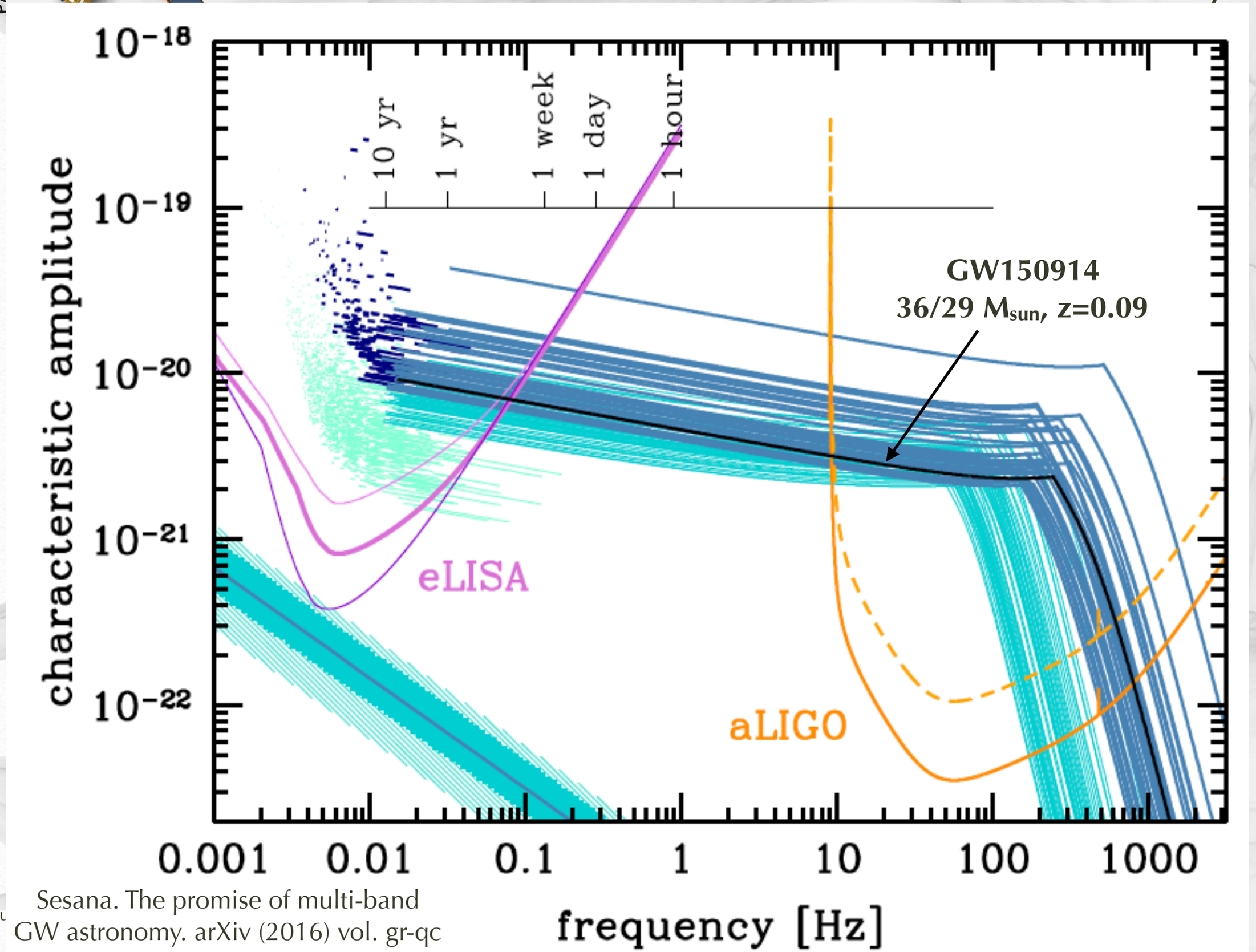


SMBH detection

SNR and merging tracks and coalescence of equal mass SMBH



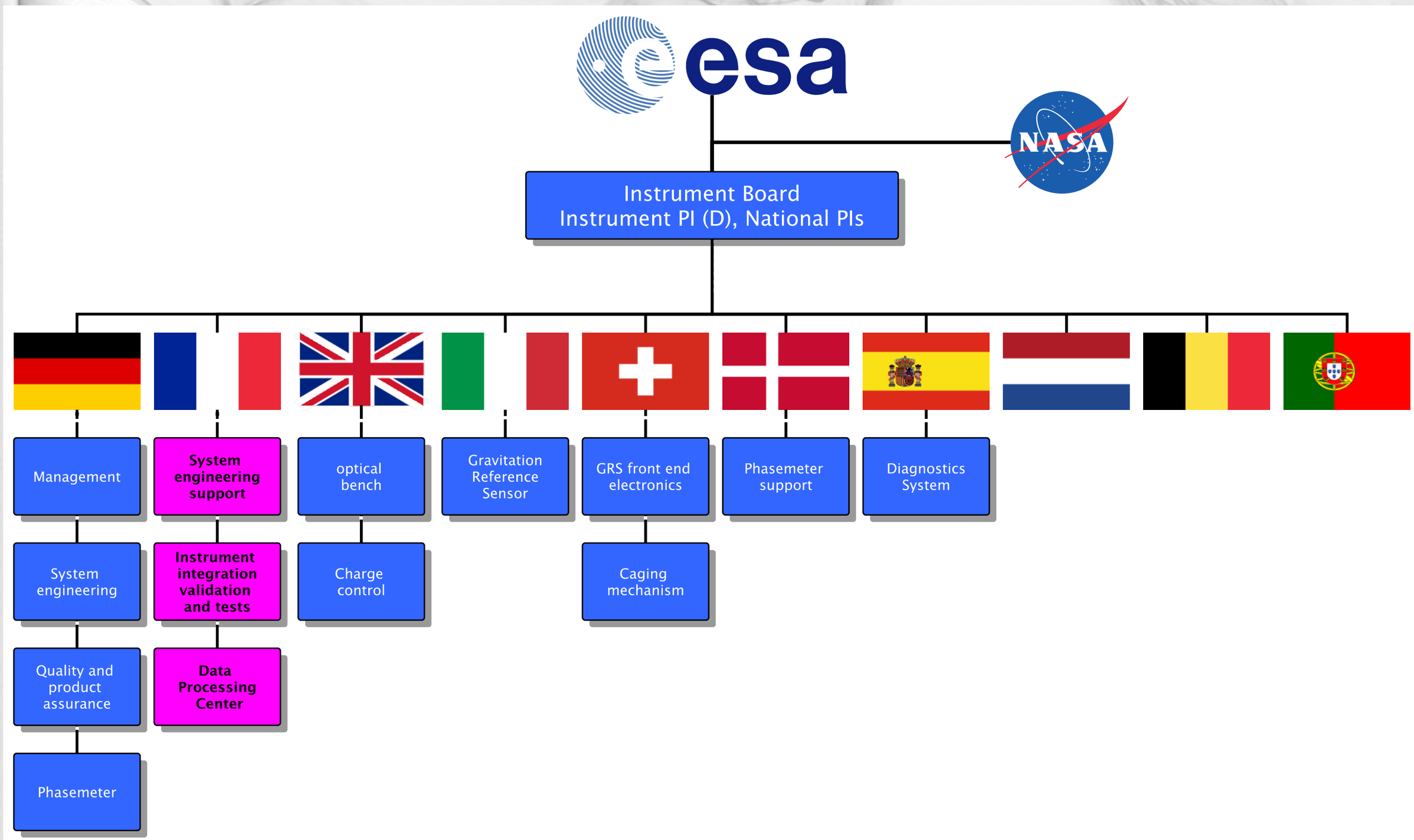
Multi-band GW Astronomy



Sesana. The promise of multi-band GW astronomy. arXiv (2016) vol. gr-qc

French contribution to eLISA

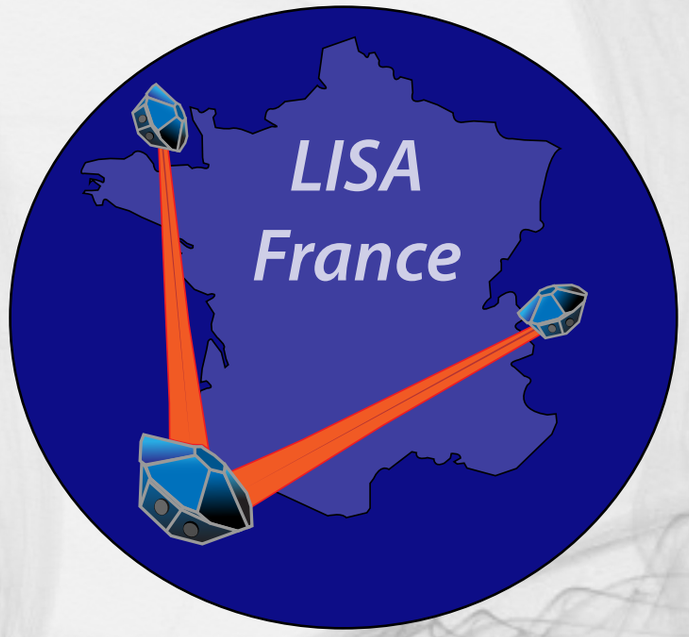
France within the eLISA consortium



France within the eLISA consortium

➡France joined the (e)LISA project in 2005
- ✓Participation to LISA Pathfinder
- ✓France took charge of supervising the realization of the laser modulator unit

➡LISA France
- ✓Federates the labs involved in the LISA project
- ✓Supported by the CNES



http://www.apc.univ-paris7.fr/LISA-France/

➡French labs involved in LISA
- ✓AstroParticule and Cosmology (APC, Paris)
- ✓ARTEMIS, Obs. de la Côte d'Azur (Nice)
- ✓Institut d'Astrophysique de Paris (IAP)
- ✓Institut de Physique Théorique, CEA (Paris)
- ✓Laboratoire de Physique et Chimie de l'Environnement et de l'Espace (LPC2E)
- ✓Laboratoire Univers et Théorie (LUTh, Paris)
- ✓SYRTE (Obs. Paris)
- ✓ONERA

➡Planned main French contributions
- ✓**Data Processing Center**
- ✓**AIVT of the instrument (test benches and performance models)**
- ✓**Support in system engineering**

Aspects programmatiques

Roadmap eLISA *a priori* ...

✓ Sélection du thème eLISA en L3	2013
✓ Travail sur la 'Technology Roadmap'	2013 – 2015
✓ Continuation des études systèmes de conception charge utile	2014 – 2015
✓ **Vol (réussi) de LISA Pathfinder**	**2016**
✓ *Phase 0 CNES sur la contribution française*	*2016*
✓ *Etudes techniques*	*2016-2017*
✓ ***Télescopes**, laser, banc optique, référence de phase*	
✓ Appel à mission par l'ESA	Automne 2016
✓ Phase A concurrentes	2017-2018
✓ Démarrage du modèle d'ingénierie de la charge utile	2019 - 2020
✓ Début des réalisations industrielles	2021 à 2024
✓ Décollage eLISA	2030 à 2033

2015 : Première détection directe des OG par les interféromètres sol !

20 ans au total, mais période cruciale : 2014-2018 ...

✓ Consolidation du concept mission, rôle de la NASA et du Consortium

✓ Pour la France :

- Participation aux études systèmes (concept mission + intégration et tests)
- Développement du Centre de Traitement de données

LISA France needs you !

➡A new window on the Universe is opening !

The contributions of French labs to eLISA must increase !

➡In astrophysics & fundamental physics:

- ✓ What can we learn from GW sources ? On stellar evolution ? On large structure formations ? When and how do BH form ?
- ✓ How far can we test GR and other theories (cosmic strings, inflation, etc.) ?
- ✓ What counterparts can be expected in the EM spectrum ? Can we use BH as standard sirens ?

➡Data analysis :

- ✓ Source modeling
- ✓ Alternative data processing algorithms
- ✓ How to deal with a (probably) source dominated signal ?

➡Instrumentation :

- ✓ Noise modeling
- ✓ Test benches design and realization
- ✓ Expertise in integration and tests for space projects
- ✓ Optical designs
- ✓ Light propagation simulations
- ✓ Phase and frequency metrology

Register on www.elisascience.org …

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eLISA

We will observe gravitational waves in space | New Astronomy | LISA Pathfinder

eLISA: THE MISSION | LISA PATHFINDER | NEW ASTRONOMY | CONTEXT 2028 | eLISA COMMUNITY

LISA Pathfinder's science operations phase started!

1 2 3 4 5 6 7 8 9 10

Test masses inside LISA Technology Package. © ESA/ATG medialab

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LISA Pathfinder on Twitter

@ESA_LPF: Follow LPF and get the latest news, information and developments from the groundbreaking mission!

»» News Overview: Latest news and consortium activities, conferences, publications, positions.

Mar 08, 2016
LISA Pathfinder Mission, Top News, Top News

Feb 16, 2016
LISA Pathfinder Mission, Top News

Feb 11, 2016
A New Astronomy, Science, Top News

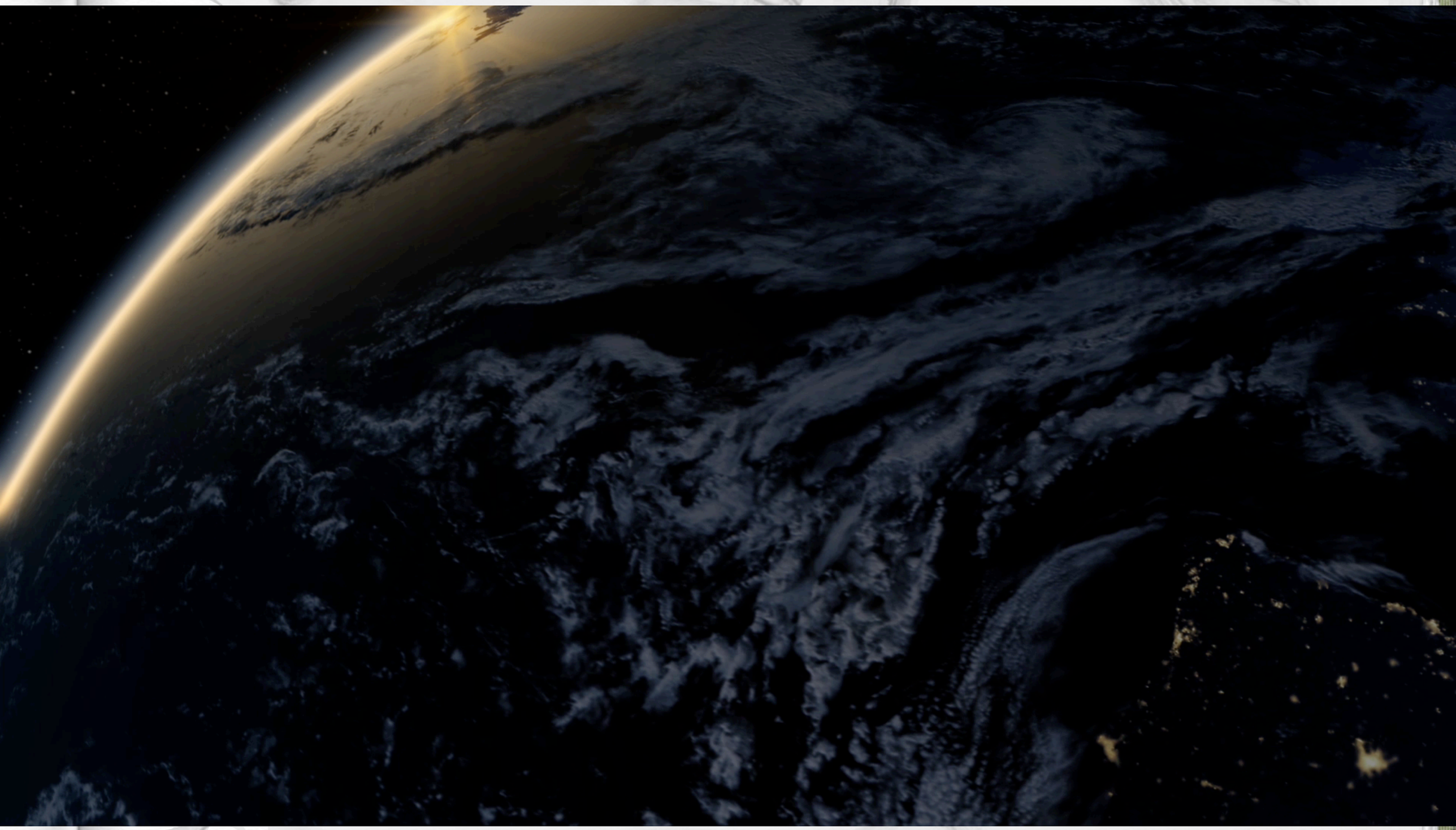
Jan 22, 2016
LISA Pathfinder Mission, Top News

Latest Consortium News

Sep 05, 2016
11th International LISA

eLISA

https://www.elisascience.org/multimedia/video/elisa-trailer



Thank you

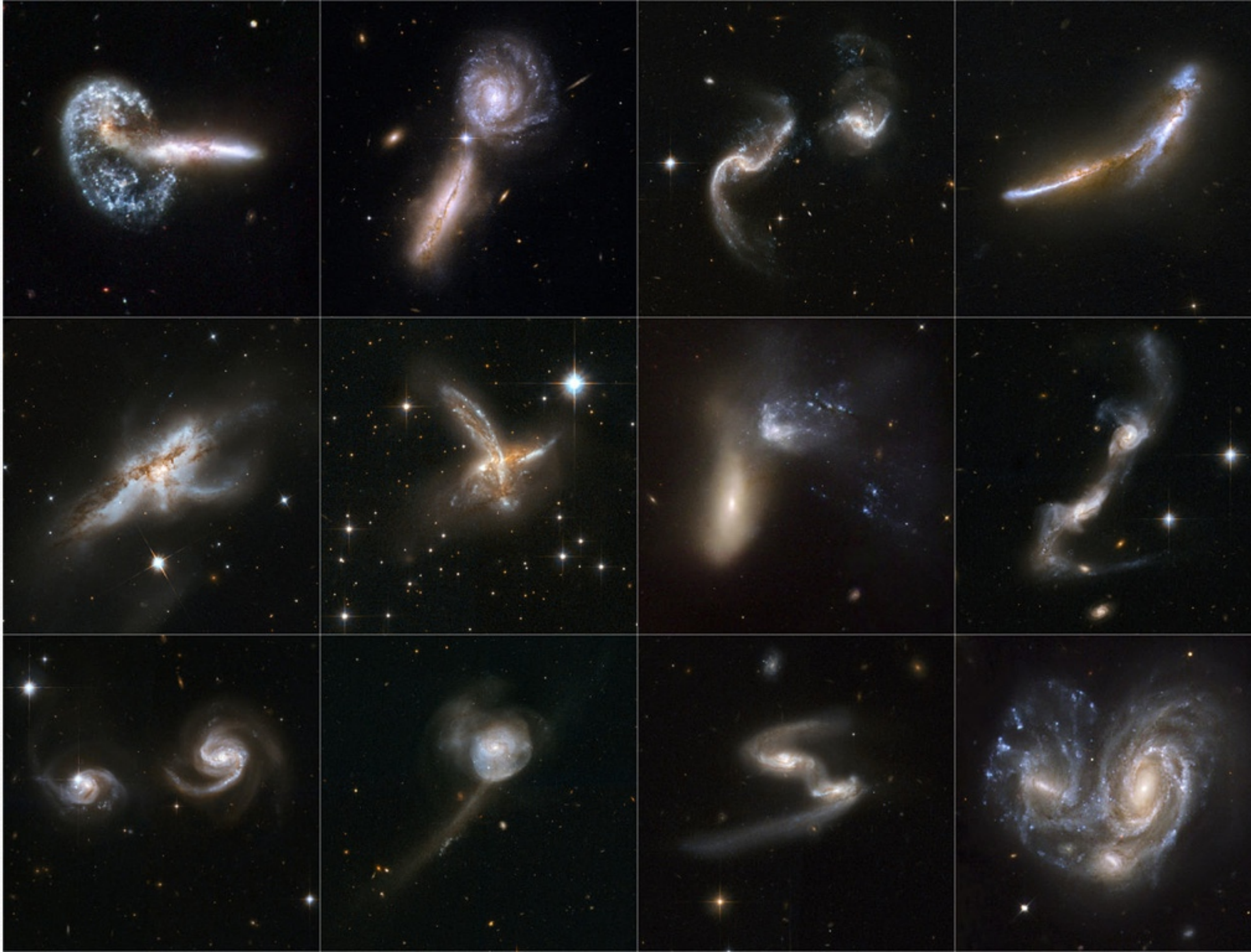
Extras

Massive Black Holes

➡Sgr A* : a dark massive object of 4.5×10^6 M_{Sun} at the centre of the Milky Way.

➡Evidence of SMBH at the center of galaxies and observations of merging galaxies
—> SMBH binaries must exist …

http://www.eso.org/public/france/videos/eso1151e/

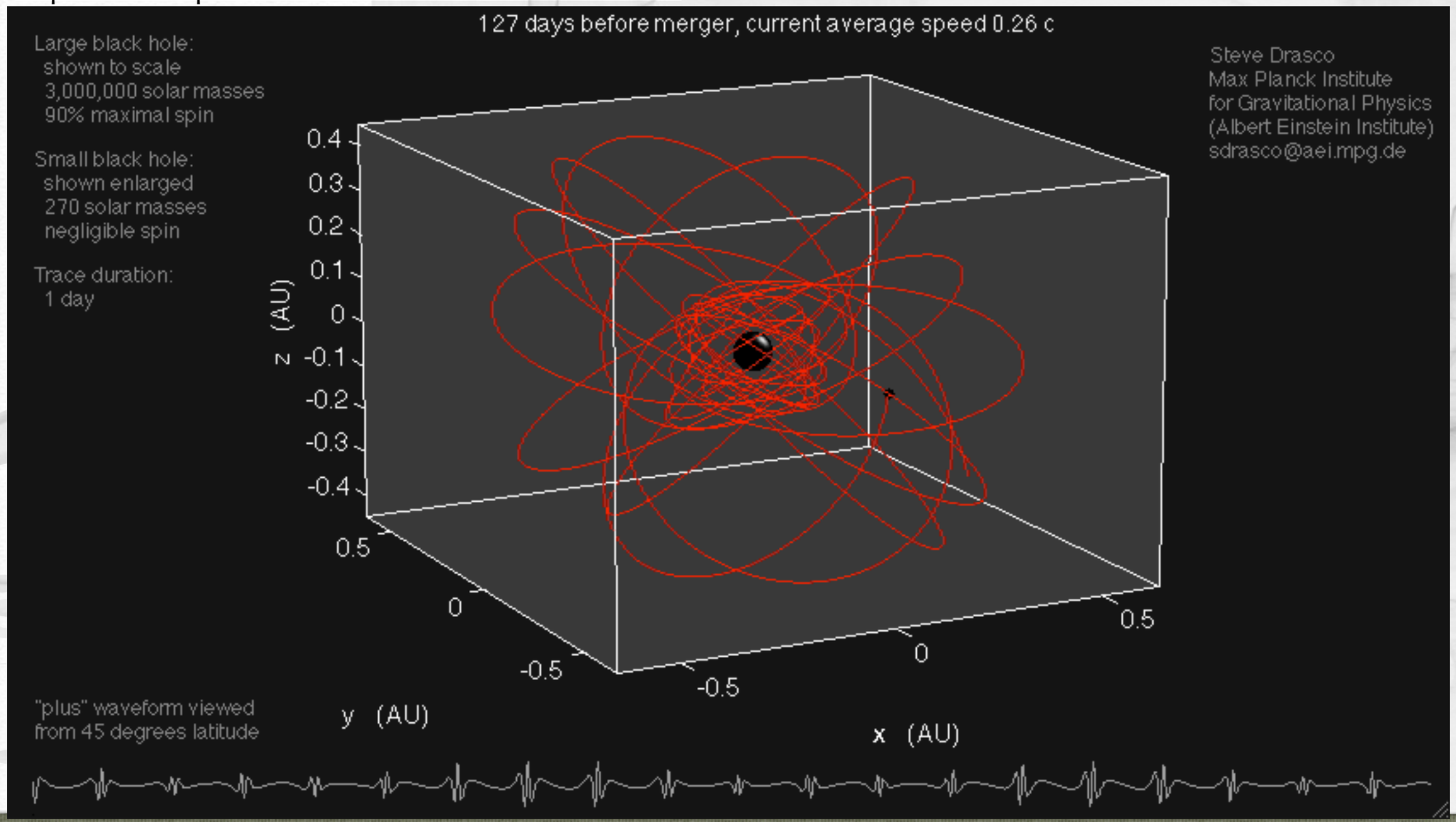


EMRIs

➡Strong (!) relativistic effects !

- ✓ Complex trajectory of the companion and gravitational waves signal.
- ✓ Models are still inaccurate : requires more simulations efforts

http://www.tapir.caltech.edu/~sdrasco/animations/



Cosmological backgrounds

➡ Produced by events in the early Universe ...