LISA

GRAVITATION and the UNIVERSE

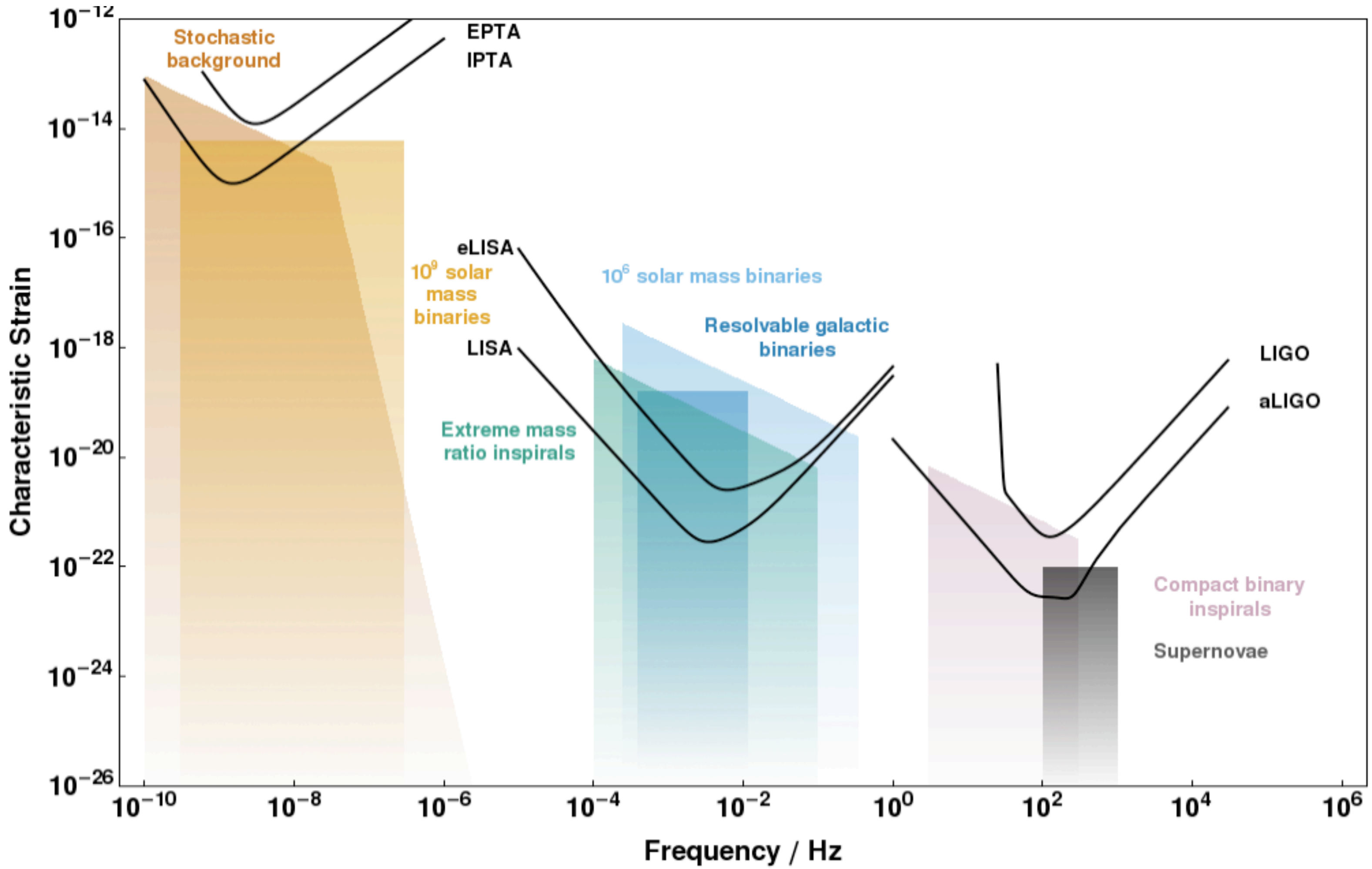
Gudrun Hiller, Dortmund

Gravity is the most immediate force experienced by humans, and perhaps one of the most mysterious; it evades so far a complete theory for quantization; In the extreme high energy regime is accessible to particle physics if the fundamental Planck scale is low (LHC) or accessible in cosmology, e.g., run time differences (depending on frequency) of light from distant sources (MAGIC).

A classical feature predicted by GR are gravitational waves

$$G_{\mu\mu} + \Lambda g_{\mu\nu} = 8\pi G T_{\mu\nu} \, , \quad (1)$$

Einstein 1916. Emitted from binary (2-body) systems. Amplitude drops as $1/r$, so typically small. In addition, wide range of frequencies.



EMRI: extreme mass ratio inspiral (orbit of light around much heavier object that gradually decays due to GW emission)

LIGO observation of BH merger 2016

It already happened 2016:

Selected for a Viewpoint in *Physics*

PRL **116,** 061102 (2016) PHYSICAL REVIEW LETTERS week
12 FEBI

Observation of Gravitational Waves from a Binary Black Hole Merger

B. P. Abbott *et al.*[*]

(LIGO Scientific Collaboration and Virgo Collaboration)

(Received 21 January 2016; published 11 February 2016)

On September 14, 2015 at 09:50:45 UTC the two detectors of the Laser Interferometer Gravitational-Wave Observatory simultaneously observed a transient gravitational-wave signal. The signal sweeps upwards in frequency from 35 to 250 Hz with a peak gravitational-wave strain of 1.0×10^{-21}. It matches the waveform predicted by general relativity for the inspiral and merger of a pair of black holes and the ringdown of the resulting single black hole. The signal was observed with a matched-filter signal-to-noise ratio of 24 and a false alarm rate estimated to be less than 1 event per 203 000 years, equivalent to a significance greater than 5.1σ. The source lies at a luminosity distance of 410^{+160}_{-180} Mpc corresponding to a redshift $z = 0.09^{+0.03}_{-0.04}$. In the source frame, the initial black hole masses are $36^{+5}_{-4} M_\odot$ and $29^{+4}_{-4} M_\odot$, and the final black hole mass is $62^{+4}_{-4} M_\odot$, with $3.0^{+0.5}_{-0.5} M_\odot c^2$ radiated in gravitational waves. All uncertainties define 90% credible intervals. These observations demonstrate the existence of binary stellar-mass black hole systems. This is the first direct detection of gravitational waves and the first observation of a binary black hole merger.

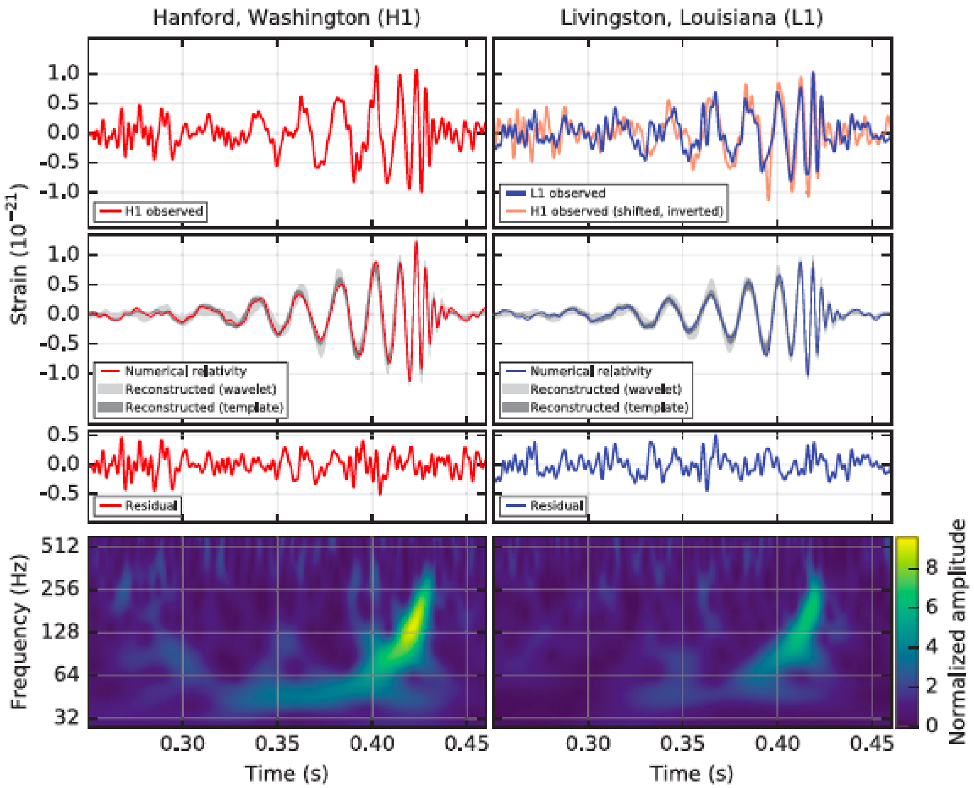
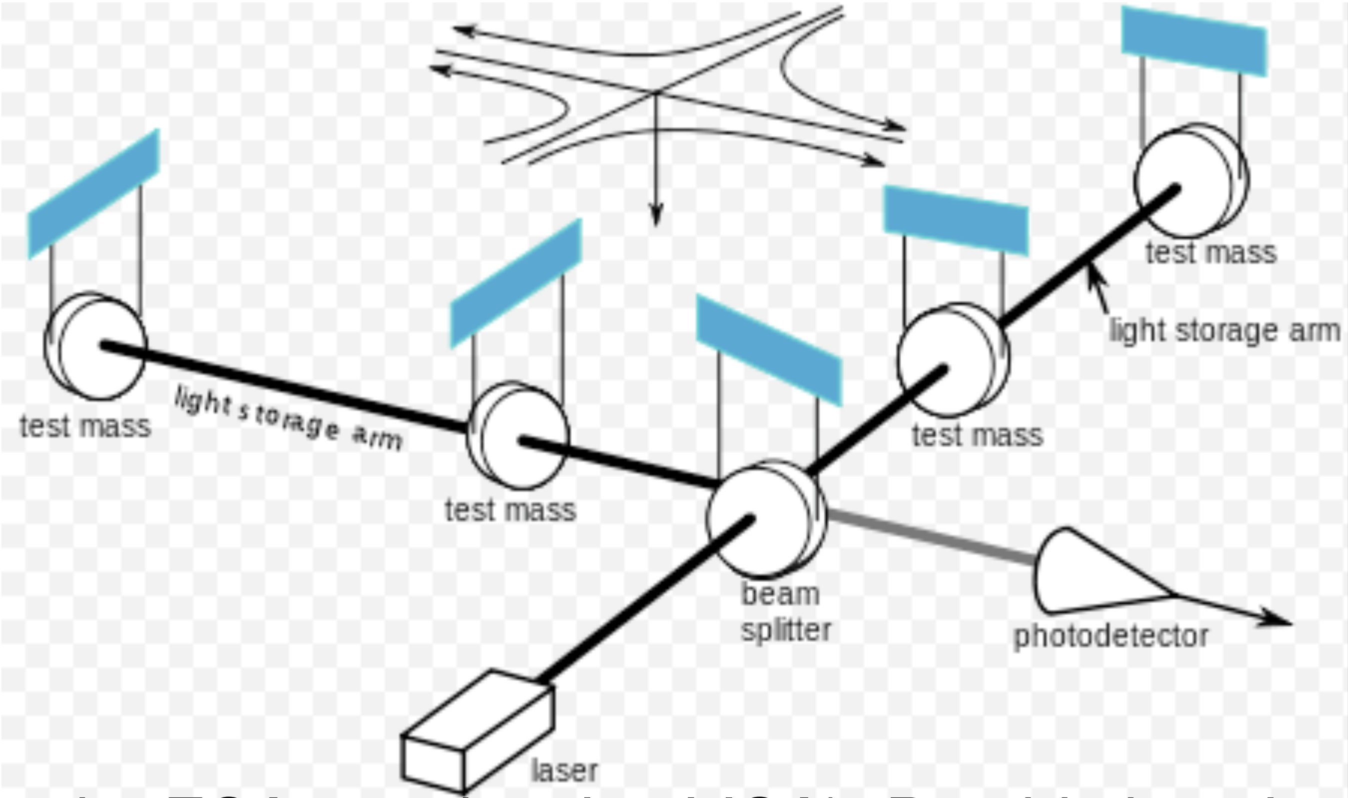


Fig from Ligo PRL

A new era of seeing the universe has began! Let us take full advantage of this. THINK BIG

interferometry



LISA (project by ESA, previously eLISA): Put this in solar orbit, have lasers on three space crafts with interferometer arms of length 5 million km. great vacuum

Laser Interferometer Space Antenna

launch date: 2034

RECENT NEWS:

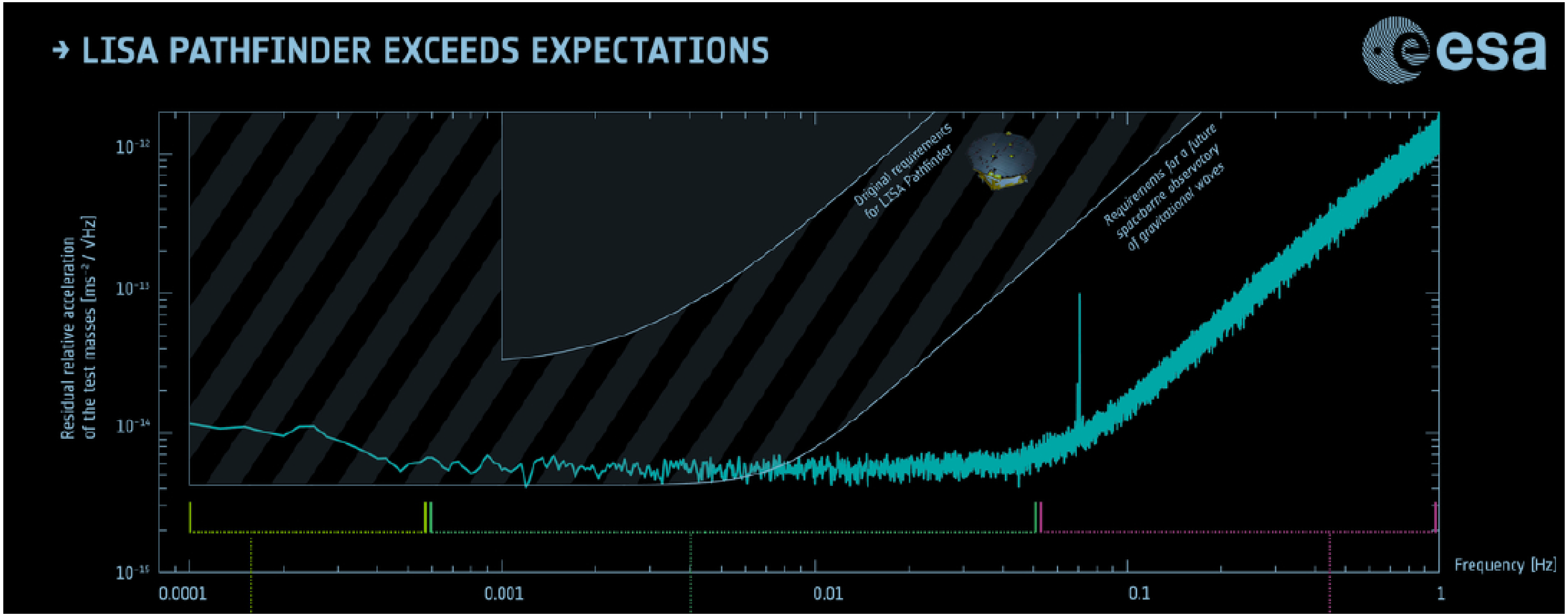
eLISA-pathfinder (proof of principle) launched Dec 3, 2015

Arrived at Lagrange Point 1 (sun/earth) Jan 22, 2016

Science mission (tests, study free fall) started Mar 8, 2016

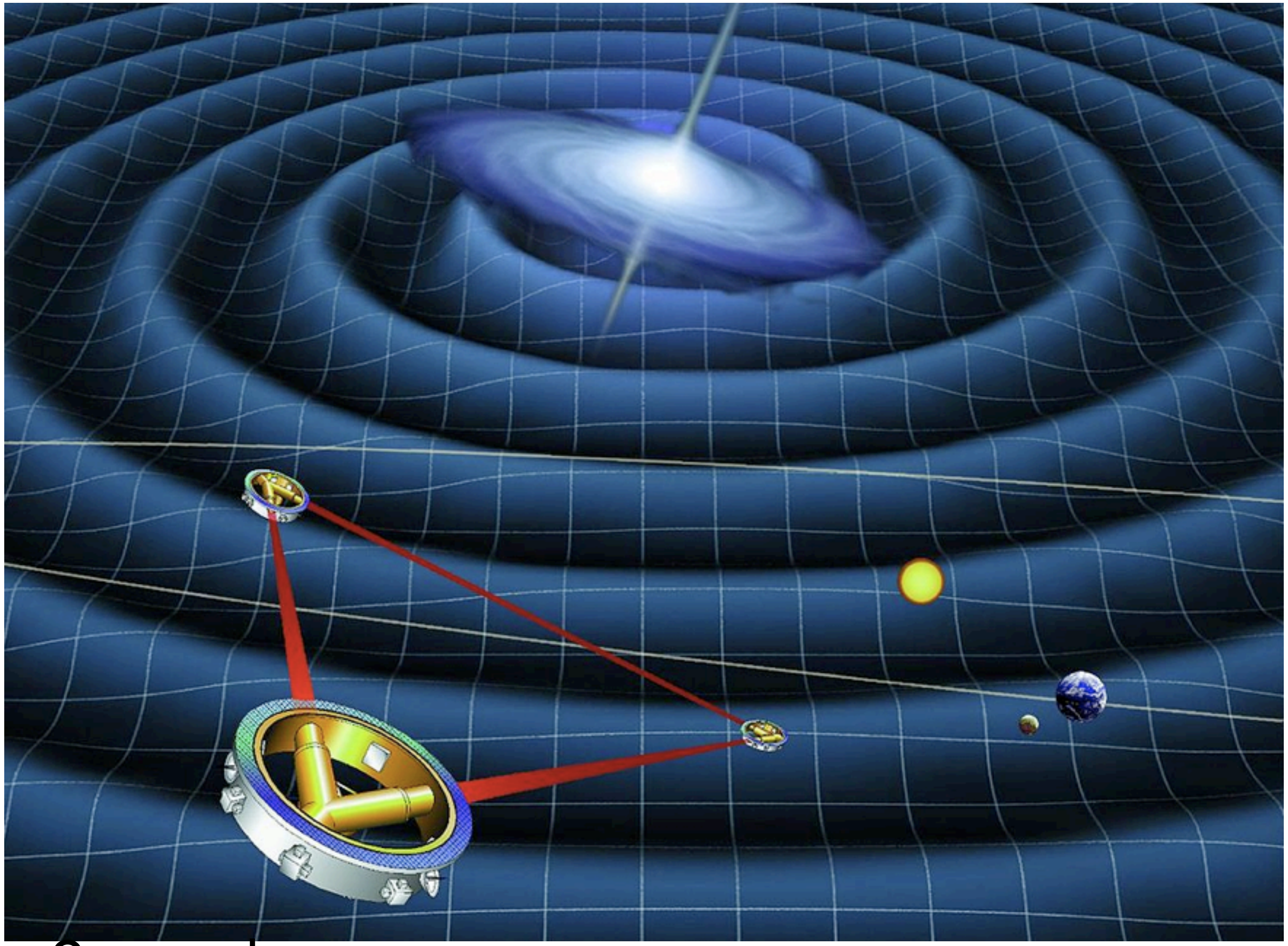
single space craft with one arm of 38 cm length to fit in a single craft.

interferometry

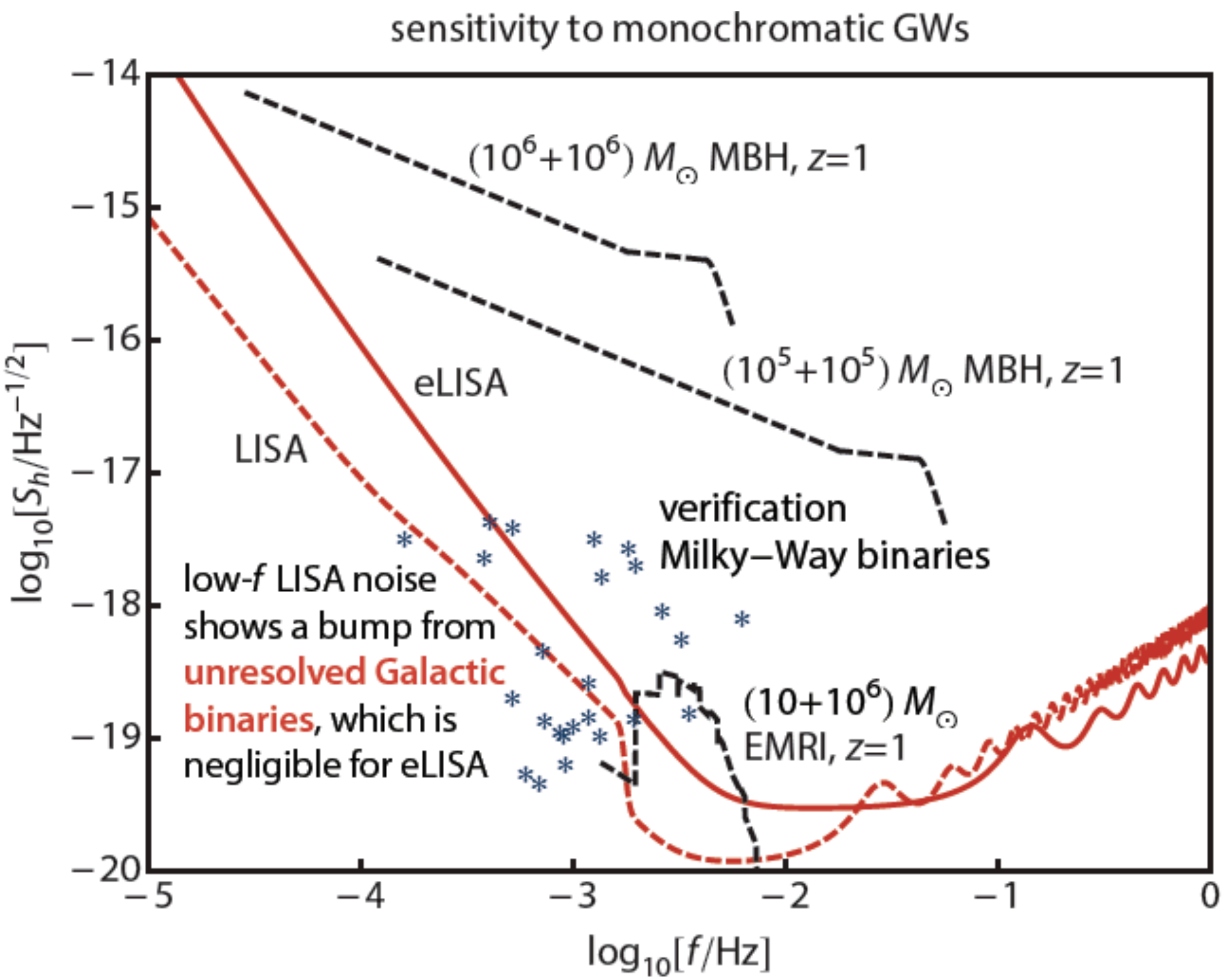


performance exceeds expectations

interferometry

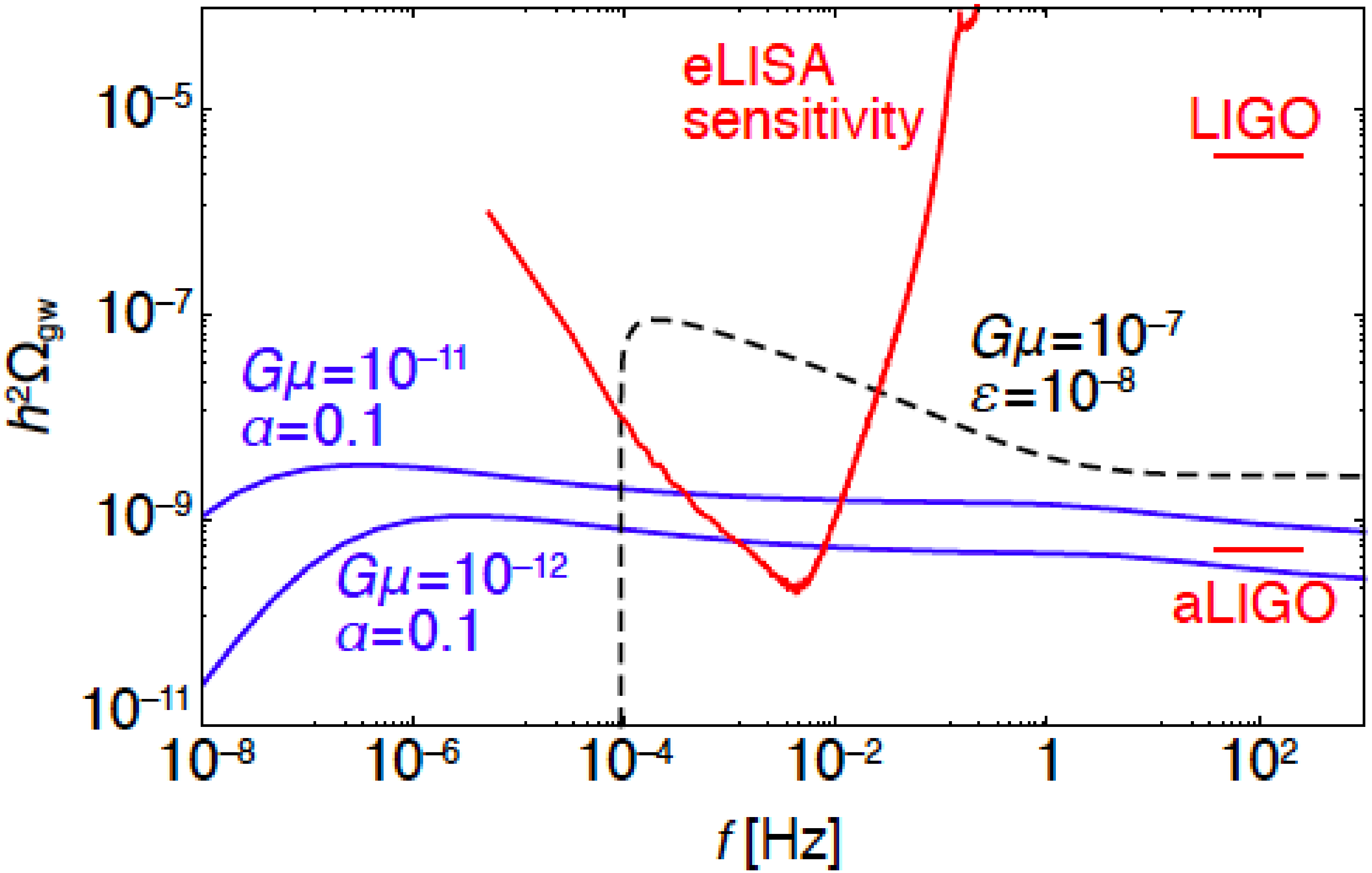


in LISA only 2 arms!



from http://vallis.org/images/graphics/2013-01-aas.pdf

http://arxiv.org/abs/1305.5720



eLISA: low frequency; from white paper 1202.0839

L2/L3 Call in Europe

- L2/L3 Call In Europe:
  - Cost: About twice ESA's annual science budget: €1000M (ESA alone)
  - + typically €250M from ESA member states (payload)
  - Compare: ESA approved costing for L1-eLISA: €1268M ~ €1250M
  - ESA can do it alone!! But what about partners??

What is an L mission?

Large missions represent the "flagships" of European science and should therefore be European-led (with Europe being responsible for upward of approximately 80% of the mission's elements). While limited international participation is possible and welcome, L missions should not rely on international cooperation for mission-enabling elements, as Europe's capability to implement the mission should be safeguarded. Historically, the cost to ESA of L missions (or cornerstone) has

slide by Guido Mueller, Monterey April 2013


A New Astronomy
The Gravitational Universe
Illuminating the dark universe with a new astronomy