A Possible U.S. Contribution to eLISA, a Gravitational-Wave Mission Concept for ESA's L2 Opportunity

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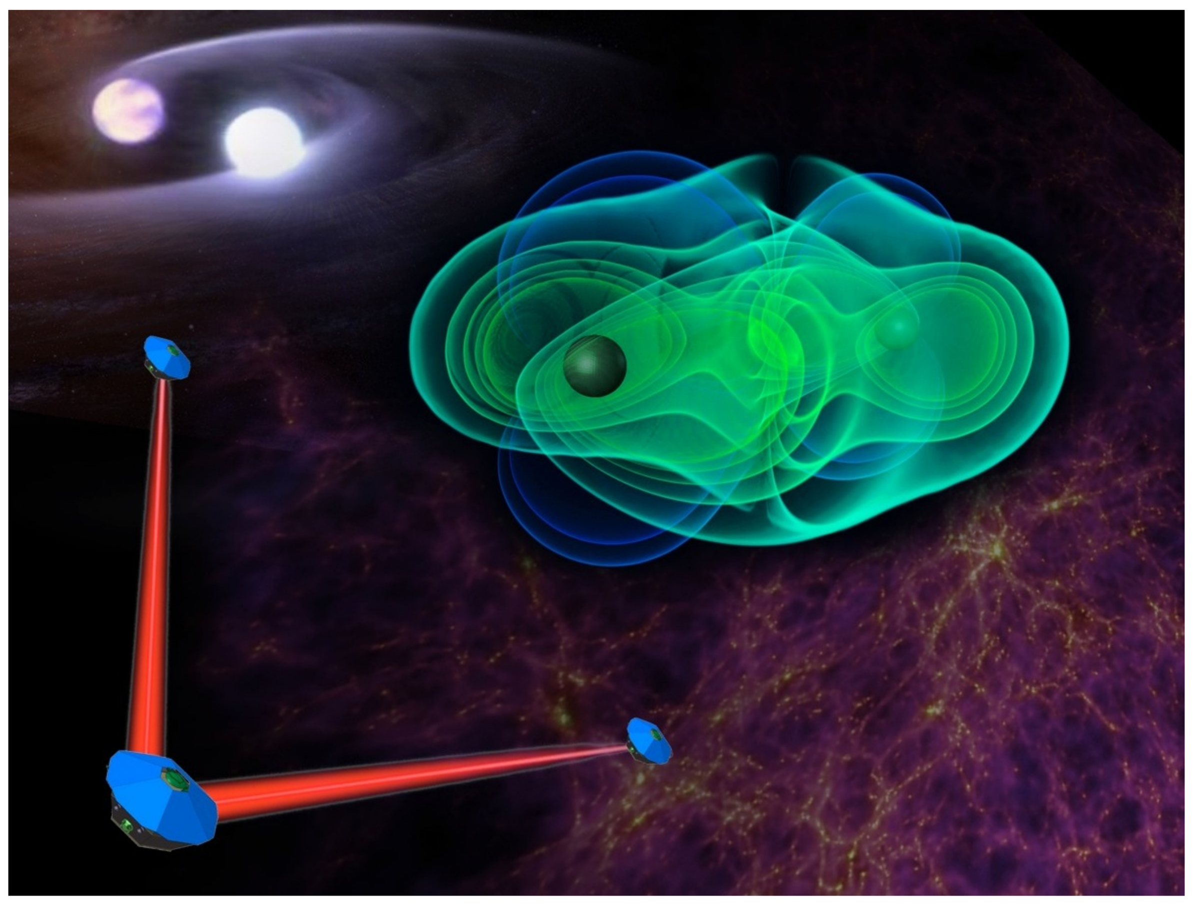
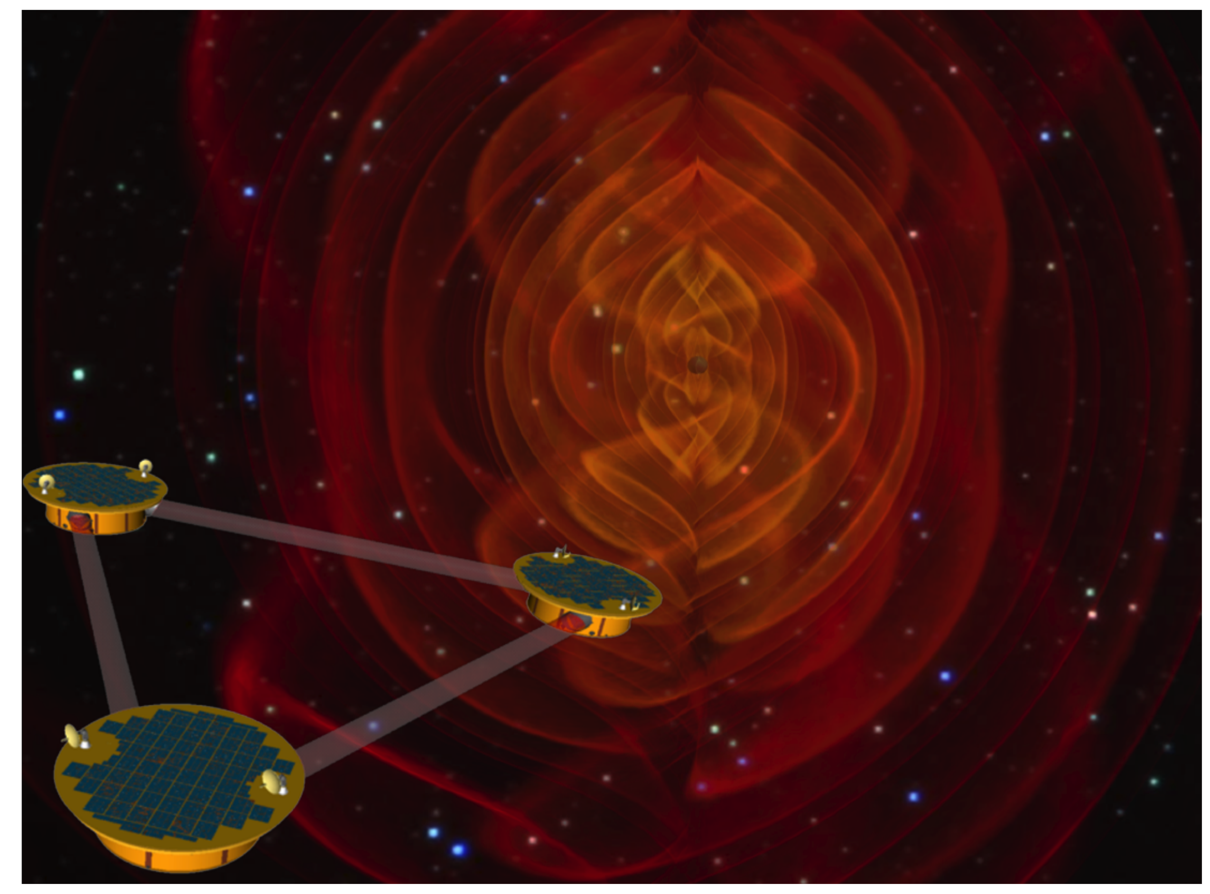


eLISA/NGO

Abstract

Scientists from the member states of the European Space Agency (ESA) that proposed the New Gravitational-Wave Observatory (NGO) have organized the eLISA Consortium to propose for ESA's next large mission opportunity. The Evolved Laser Interferometer Space Antenna (eLISA) concept is derived from the well-studied LISA concept for a space-based, gravitational-wave detector. eLISA will use the technology being developed by the LISA Pathfinder mission in a two-arm version that achieves much of the LISA science endorsed by the Decadal Survey. If invited, NASA could join the project as a junior partner with a ~20% share. This could enable a third arm and substantially augment the science return. While the details of the eLISA concept to be proposed have not yet been finalized, the SGO Mid concept, recently studied in the U.S., constitutes a possible augmented concept for an ESA/NASA partnership. The eLISA concept and the SGO Mid concept are described and compared.



SGO Mid

Introduction

In March 2013, ESA issued a call for science themes for the L2 and L3 (second and third large) mission opportunities in their Cosmic Vision Programme. The selection of two science themes later this year will be followed by a call for mission concepts to carry out the selected science. The mission most ready to proceed will subsequently be selected for launch in 2028.

If NASA were invited to participate as a minor partner (20%) in an ESA-led L2 mission, it could enable the addition of a third arm. This enhancement is the most attractive science augmentation for NASA to support. The recently studied SGO Mid concept (Space-based Gravitational-wave Observatory Mid-size) is a likely realization of eLISA/NGO with three arms. The table below compares the NGO and SGO-Mid designs. The text and table below that summarize the enhanced science return. The classic LISA design, endorsed by the Astro2010 decadal report, is also shown for reference.

Instrument Characteristics

Parameter	eLISA/NGO	SGO Mid	Classic LISA
Measurement arm length	1 x 10^6 km	1 x 10^6 km	5 x 10^6 km
Number & type of spacecraft	1 corner (2 optical assemblies), 2 end (single optical assembly)	3 corner (2 optical assemblies)	3 corner (2 optical assemblies)
Constellation configuration	Vee	Triangle	Triangle
Interferometer configuration	2 arms, 4 links	3 arms, 6 links	3 arms, 6 links
Gravitational-wave polarization measurement	Single instantaneous polarization, second polarization by orbital evolution	Two simultaneous polarizations continuously	Two simultaneous polarizations continuously
Orbit	Heliocentric, earth-trailing, drifting-away 9°- 21°	Heliocentric, earth-trailing, drifting-away 9°- 21°	22° heliocentric, earth-trailing
Trajectory	Launch to Geosynchronous Transfer Orbit, transfer to escape, 14 months	Direct injection to escape, 18 months	Direct injection to escape, 14 months
Duration of science observations	2 years, extendable to 4 years	2 years, extendable to 4 years	5 years, extendable to 8.5 years
Launch vehicle(s)	Two Soyuz	Single Medium EELV (e.g., Atlas 551)	Single Medium EELV (e.g., Falcon Heavy)
Optical bench	Low-CTE material, hydroxy-catalysis construction	Low-CTE material, hydroxy-catalysis construction	Low-CTE material, hydroxy-catalysis construction
Laser	2 W, 1064 nm, frequency and power stabilized	1 W, 1064 nm, frequency and power stabilized	2 W, 1064 nm, frequency and power stabilized
Telescope	20 cm diameter, off-axis	25 cm diameter, on-axis	40 cm diameter, on-axis
Gravitational Reference Sensor	46 mm cubical test mass - Au:Pt alloy, electrostatically controlled, optical readout	46 mm cubical test mass - Au:Pt alloy, electrostatically controlled, optical readout	46 mm cubical test mass - Au:Pt alloy, electrostatically controlled, optical readout

Science Enhancements from a Third Arm

The two-armed eLISA/NGO mission concept as proposed for L1 produces most of the LISA science endorsed in the Astro2010 decadal at a reduced cost.

While the performance of the L1 version of eLISA/NGO has not been assessed exactly as the performance of SGO Mid and Classic LISA, the table below is reasonably representative of the performance with respect to numbers of sources detected for each of 3 types. However the precision with which astrophysical parameters can be extracted from the signal depends subtly on the interplay between detector response and the waveform. Designs with three arms are able to make instantaneous measurements of both gravitational-wave polarization states, which proves to be a key factor in breaking degeneracies between orbital inclination, distance, and sky location for these burst-like signals. In contrast, the signal-to-noise from galactic binaries and EMRIs accumulates steadily over several years, allowing polarization information to be extracted from the evolving projection onto the antenna pattern, thus lessening the impact of having two rather than three arms.

The third arm will have the following benefits: better parameter estimation with simultaneous two-polarization detection; better sky locations, better mass determinations, better spin determinations and lower distance errors for massive black hole binaries; more robust stochastic background searches; more secure identification of unexpected signals; and higher reliability. Notably, the improved sky locations greatly facilitate searches for electromagnetic counterparts for multi-messenger astronomy.

Science Performance

Source	eLISA/NGO	SGO Mid	Classic LISA
Massive black hole mergers	20 - 200	40 - 50	110 - 220
Extreme mass ratio inspirals (EMRIs)	20 - 40	~ 35	~ 800
Galactic binaries	~ 3,000	~ 7,000	~ 40,000