**Possible Space-based Gravitational-wave Observatory Mission Concept**

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### Abstract

The existence of gravitational waves was established by the discovery of the binary pulsar PSR 1913+16 by Hulse and Taylor in 1974, for which they were awarded the 1993 Nobel Prize. However, it is the exploitation of these gravitational waves for the extraction of the astrophysical parameters of the sources that will open the first new astronomical window since the development of gamma ray telescopes in the 1970’s and enable a new era of discovery and understanding of the Universe. Direct detection is expected in at least two frequency bands from the ground before the end of the decade with Advanced LIGO and Pulsar Timing Arrays. However, many of the most exciting sources will be continuously observable in the band from 0.1-100 mHz, accessible only from space due to seismic noise and gravity gradients in that band that disturb ground-based observatories. This poster will discuss a possible mission concept, Space-based Gravitational-wave Observatory (SGO-Mid) developed from the original Laser Interferometer Space Antenna (LISA) reference mission but updated to reduce risk and cost.

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### SGO-Mid Mission Summary

- **Mission Design**  
  - 10^18 km arm-length  
  - 3 arms, 60 deg triangle  
  - LISA-like payload  
  - 25 cm telescope/1 W laser  
  - 9-21 degree drift away heliocentric orbit  
  - Direct injection to escape, 18 mo transfer  
  - Single EELV (e.g., Falcon 9 Block 3)  
  - Baseline 2 year lifetime + 2 years  
  - Limited by communications bandwidth

- **3 Identical arms enable simultaneous measurement of both polarizations of gravitational waves, which is essential for parameter extraction, particularly of transient events such as mergers.**

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### Mission Timeline

24 months science operations: orbits optimized for 48 months

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### Summary

The LISA-like mission concept SGO-Mid is based on the baseline LISA mission design, but has been updated to reduce risk and cost. The main differences with the baseline are the shorter armlength (1 million km instead of 5) and the mission lifetime (2 years instead of 5). Science return is maximized by keeping three arms to allow simultaneous measurement of both polarizations as well as a Sagnac configuration that allows correct measurement of the noise. Drift away orbits offer graceful degradation as the constellation moves out of communications range.

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### Mission Concept Comparison

<table>
<thead>
<tr>
<th>Parameter</th>
<th>This poster</th>
<th>LISA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement arm length</td>
<td>1 x 10^7 km</td>
<td>5 x 10^4 km</td>
</tr>
<tr>
<td>Number &amp; type of spacecraft</td>
<td>1 corner (2 optical assemblies, 2 end (single optical assembly)</td>
<td>3 corner (2 optical assemblies)</td>
</tr>
<tr>
<td>Number of measurement arms, one-way links</td>
<td>2 arms, 4 links</td>
<td>3 arms, 6 links</td>
</tr>
<tr>
<td>Constellation</td>
<td>Vega</td>
<td>Triangle</td>
</tr>
<tr>
<td>Gravitational-wave polarization measurement</td>
<td>Single instantaneous polarization, second polarization by orbital evolution</td>
<td>Two simultaneous polarizations continuously</td>
</tr>
<tr>
<td>Orbit</td>
<td>Helio-centric, earth-boring, slightly away 0 - 21°</td>
<td>21° helio-centric, earth-boring</td>
</tr>
<tr>
<td>Trajectory</td>
<td>Launch to Geosynchronous Transfer Orbit, transfer to escape, 14 months</td>
<td>Direct injection to escape, 14 months</td>
</tr>
<tr>
<td>Duration of science observations</td>
<td>2 years</td>
<td>5 years</td>
</tr>
<tr>
<td>Launch vehicle</td>
<td>Two Soyuz-Fregal</td>
<td>Single Medium EELV (e.g., Falcon 5 Block 3)</td>
</tr>
<tr>
<td>Optical bench</td>
<td>Low-CTE material, hydroxycalixarene construction</td>
<td>Low-CTE material, hydroxycalixarene construction</td>
</tr>
<tr>
<td>Laser</td>
<td>2 W, 1064 m, frequency and power stabilized</td>
<td>2 W, 1064 m, frequency and power stabilized</td>
</tr>
<tr>
<td>Telescope</td>
<td>20 cm diameter, off-axis</td>
<td>25 cm diameter, on-axis</td>
</tr>
<tr>
<td>Gravitational Reference Sensor</td>
<td>46 mm cube Au/Pt, electrostatically controlled, optical readout</td>
<td>46 mm cube Au/Pt, electrostatically controlled, optical readout</td>
</tr>
</tbody>
</table>

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### Science Comparison

<table>
<thead>
<tr>
<th>Parameter</th>
<th>This poster</th>
<th>LISA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Massive Black Hole Binary Totals</td>
<td>40-47</td>
<td>4 - 52</td>
</tr>
<tr>
<td>Detected &gt; 10</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Both mass errors &lt; 1%</td>
<td>13-30</td>
<td>18-42</td>
</tr>
<tr>
<td>One spin error &lt; 1%</td>
<td>3-10</td>
<td>11-27</td>
</tr>
<tr>
<td>Both spin errors &lt; 1%</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Distance error &lt; 3%</td>
<td>3-5</td>
<td>12-22</td>
</tr>
<tr>
<td>Sky location &lt; 1 deg²</td>
<td>1-3</td>
<td>14-21</td>
</tr>
<tr>
<td>Sky location &lt; 0.1 deg²</td>
<td>&lt;1</td>
<td>4-8</td>
</tr>
<tr>
<td>Extreme Mass-Radius ratios</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Resolved Compact WD Binary</td>
<td>3,889</td>
<td>7,000</td>
</tr>
<tr>
<td>Interacting</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>Detached</td>
<td>5,000</td>
<td>8,000</td>
</tr>
<tr>
<td>Sky location &lt; 1 deg²</td>
<td>1,053</td>
<td>2,000</td>
</tr>
<tr>
<td>Sky location &lt; 0.1 deg²</td>
<td>533</td>
<td>800</td>
</tr>
<tr>
<td>Stochastic Background (normalized)</td>
<td>0.2</td>
<td>1</td>
</tr>
</tbody>
</table>

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### Sciencecraft

- Full Sciencecraft Bus
- Disturbance Reduction System Detail
- Interferometry Measurement System Detail
- Launch Stack in 5 m Fairing
- Science Orbits
- Solar array not shown for clarity
- Collodial µN thrusters

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### Propagation Module

- Telescope assembly
- Mission Timeline
- 4 months commissioning

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### Falcon Heavy EELV

- Mission Operations
- Science Orbits
- Pre-Launch
- Launch
- Science Operations

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**Final report:** http://pcos.gsfc.nasa.gov/studies/gravitational-wave-mission.php