Space-based Gravitational-wave Observatory (SGO)-Mid

Minimum Cost 3-arm/6-link LISA-like Mission

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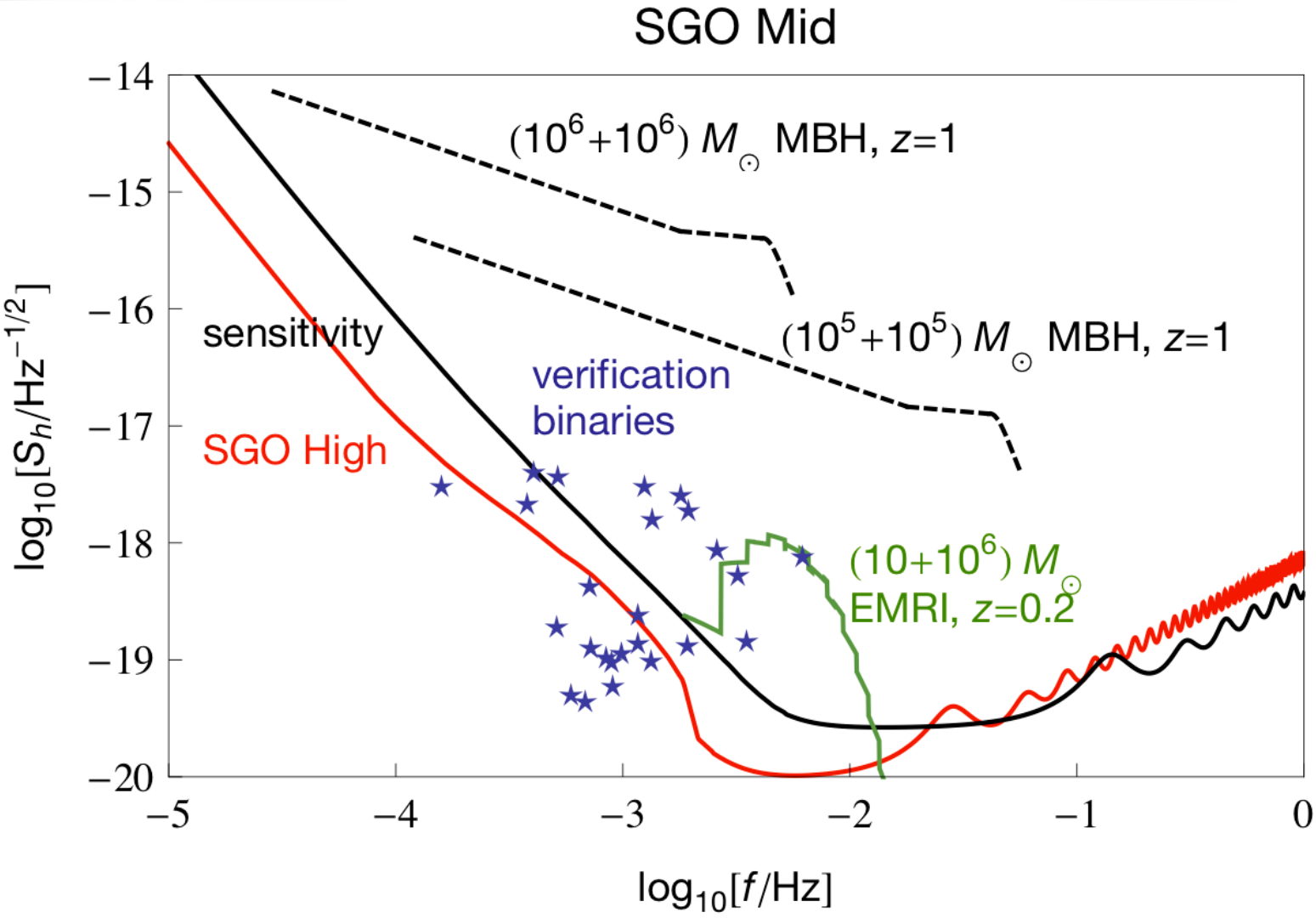
for the SGO Core Team

Concept Description

- **Rationale for the configuration**
  - Try to find lowest cost 6 links for LISA-like mission
  - Benefits of 6 links
    - Instantaneous/continuous polarization information
    - Sagnac enables noise estimation
    - Redundancy: tolerates loss of up to 2 links while still doing science
- **SGO-Mid differs from LISA by:**
  - Arm length reduced from 5 to 1 Gm
  - Mission length reduced from 5 to 2 years.
  - Starting distance from Earth reduced by ~2.5X to a 9-degree trailing orbit.
  - Telescope diameter reduced from 40 to 25 cm
  - Laser power out of telescope reduced from 1.2 to 0.7 W (end of life).
  - In-field guiding instead of articulating optical assembly

SGO-Mid Science



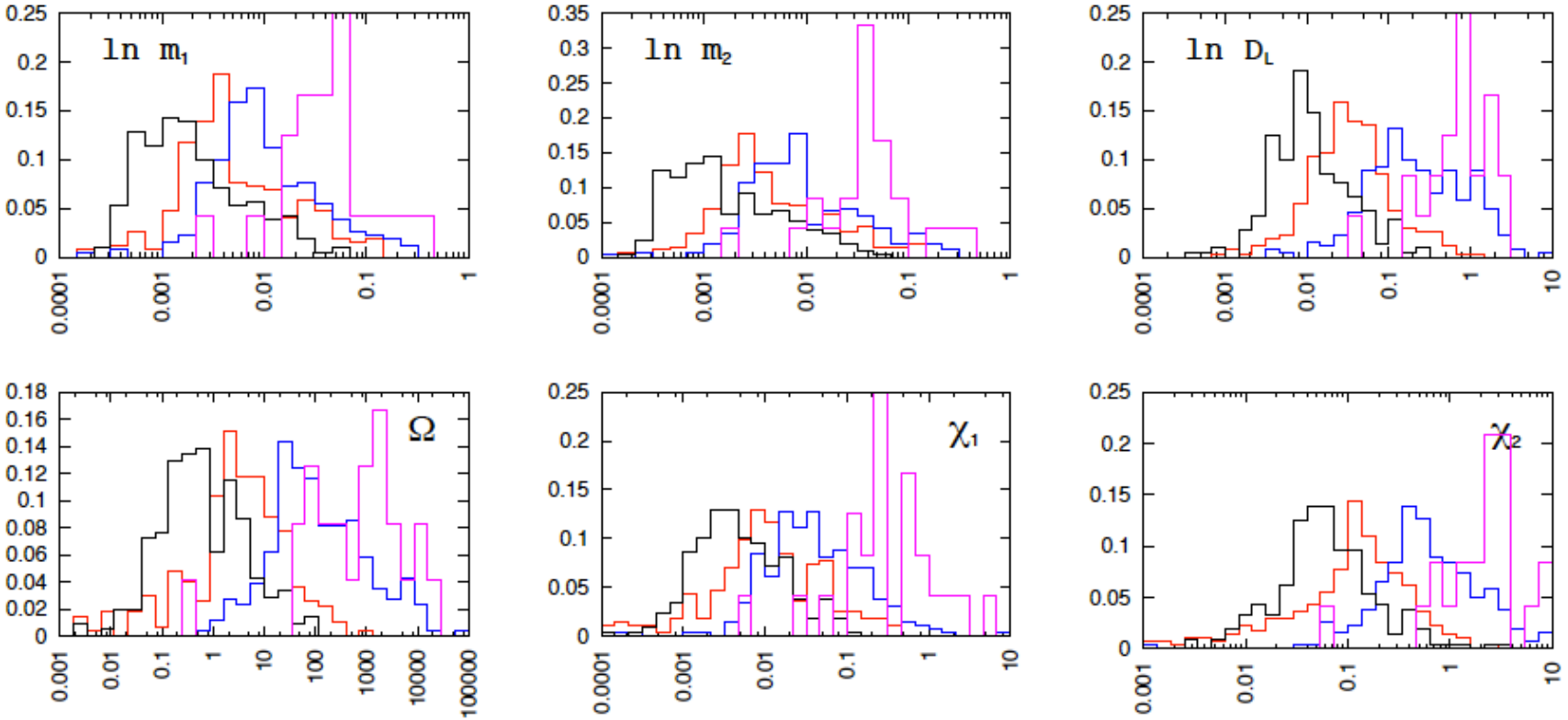
SGO-Mid Science

Comparison of Science Performance for different versions of SGO				
	SGO High	SGO Mid	SGO Low	SGO Lowest
Compact Binaries				
# Verification binaries	10	8	7	0
# Resolvable binaries	$\sim 20,000$	$\sim 4,000$	$\sim 2,000$	~ 100
MBH mergers				
# Detections	~ 150	~ 35	~ 30	~ 5
Mass Measurement Accuracy	$\frac{\sigma_M}{M} \sim 0.1\%$	$\frac{\sigma_M}{M} \sim 0.3\%$	$\frac{\sigma_M}{M} \sim 0.3\%$	$\sim 3\%$
Spin Accuracy	$\sigma\chi \sim 1\%$	$\sigma\chi \sim 3\%$	$\sigma\chi \sim 10\%$	$\sigma\chi \sim 60\%$
Distance Accuracy @ z=1	$\frac{\sigma_{D_L}}{D_L} \sim 3\%$	$\frac{\sigma_{D_L}}{D_L} \sim 5\% tbc$	$\frac{\sigma_{D_L}}{D_L} \sim 20\% tbc$	$\frac{\sigma_{D_L}}{D_L} \sim 60\%$
Angular Resolution	$\sim 1^\circ$	$\sim 3^\circ$	$\sim 10^\circ$	$\sim 30^\circ$
EMRIs				
# Detections	~ 3800, to $z \sim 1.0$	~ 200, to $z \sim 0.2$	~ 40, to $z \sim 0.15$	0
Mass Accuracy	$\frac{\sigma_M}{M} \sim 0.01\%$	$\frac{\sigma_M}{M} \sim 0.01\%$	$\frac{\sigma_M}{M} \sim 0.01\%$	–
MBH Spin Accuracy	$\sigma\chi \sim 0.01\%$	$\sigma\chi \sim 0.01\%$	$\sigma\chi \sim 0.01\%$	–
Discovery Space				
Detects early-universe Ω_{gw}	$\gtrsim 10^{-10}$	$\gtrsim 10^{-9}$	–	–
Can Detect+Verify Bursts?	✓	✓	–	–

- **Covers decadal-endorsed science**
  - Generally detects fewer sources of all types
- **Main science risk is shortened mission duration**
  - Event rates uncertain
  - Science return lower if event rates are lower

Parameter Estimation

Massive BHs, LISA-like missions

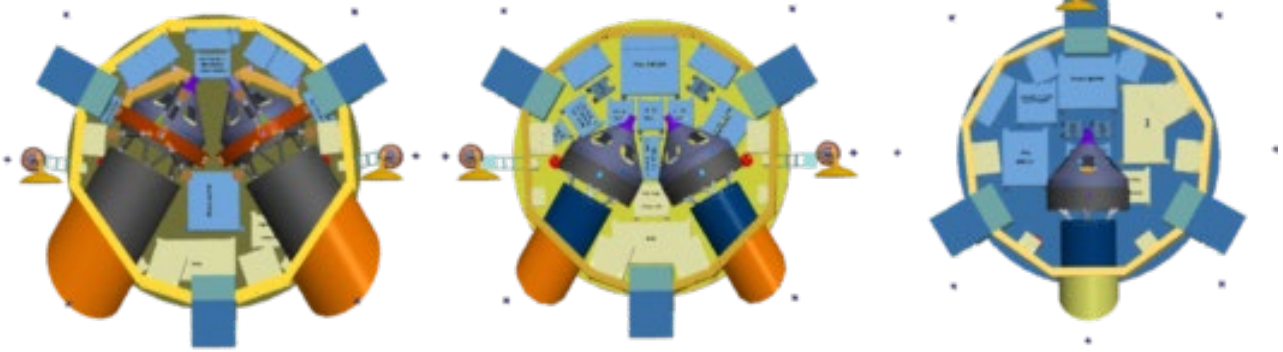


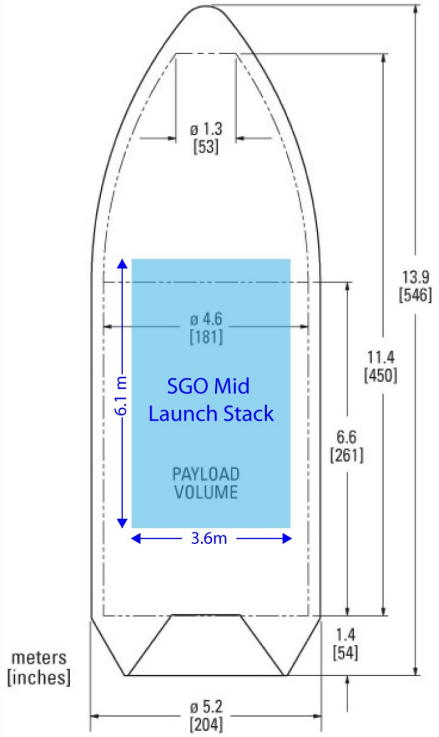
SGO hi SGO mid SGO lo SGO lowest

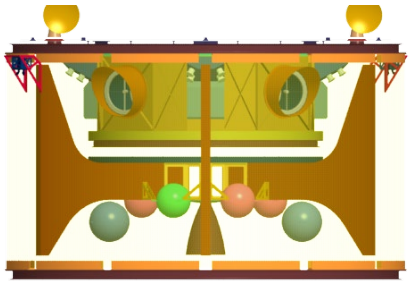
Similar detection numbers, but each descope x 3-10 loss in resolution

SGO-Mid Configuration

High Mid Low

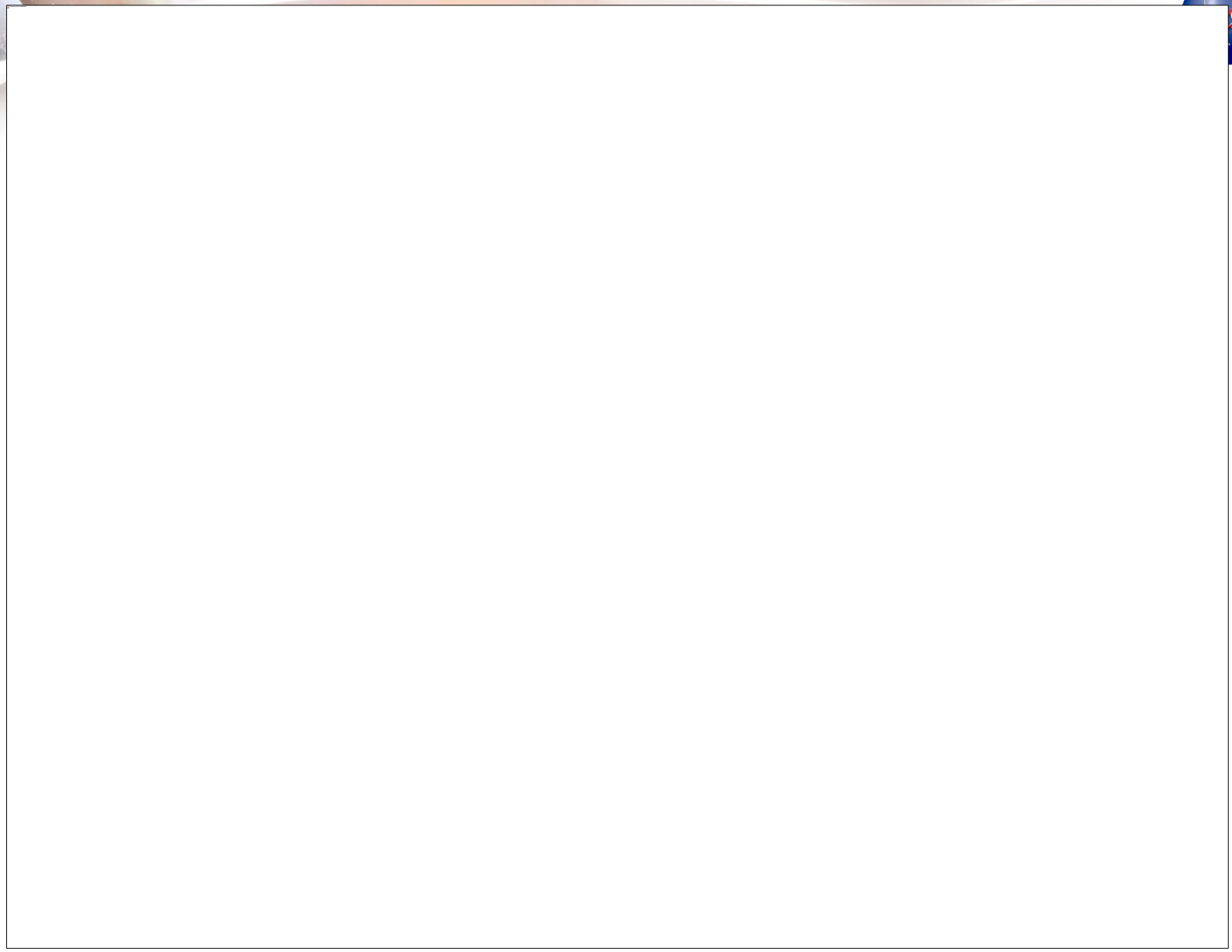






- Small telescope means optical bench sets height
- In-field guiding simplifies optical assembly
- Launch stack fits easily into a Falcoln 9 fairing
- drift away orbit requires little fuel, simplifying prop module

Scientific Payload



Orbits/trajectory

- **2 year drift-away**
  - ~ 6 deg/year drift rate starting at 9 degrees
  - 2 year end of mission similar to nominal SGO-high orbital station
  - Communications requirements similar to SGO-high
- **Stable constellation**
  - $\Delta L/L$ ~0.06
  - $\Delta\alpha$ ~ 0.6°
  - Δv ~ 2 m/s
- **18 month trajectory**
  - Optimized ΔV ~ 130 m/s (each)

Cost Estimate

SGO High Estimate	**$1.66 B**
Launch vehicle savings	-$0.03
Payload mass/redundancy reduction	-$0.11
Mission duration reduction	-$0.12
SGO Mid Total	**$1.40 B**

- **Cost model includes**
  - Non-recurring Engineering costs
  - “learning curve” for multiple copies
  - 20% additional management reserves
  - Scaling with mission lifetime
- **Scaling rates for NRE, learning curve based on**
  - Spacecraft/Vehicle-Level Cost Model
  - NASA/Air Force Cost Model