*A GEOstationary GRAvitational Wave Interferometer (GEOGRAWI)

Massimo Tinto**
Jet Propulsion Laboratory,
California Institute of Technology

* This Mission concept has also been conceived & proposed independently by Sean T. McWilliams (see next presentation)

** Work performed in collaboration with O.D. Aguiar, JCN de Araujo, and M.E.S. Alves

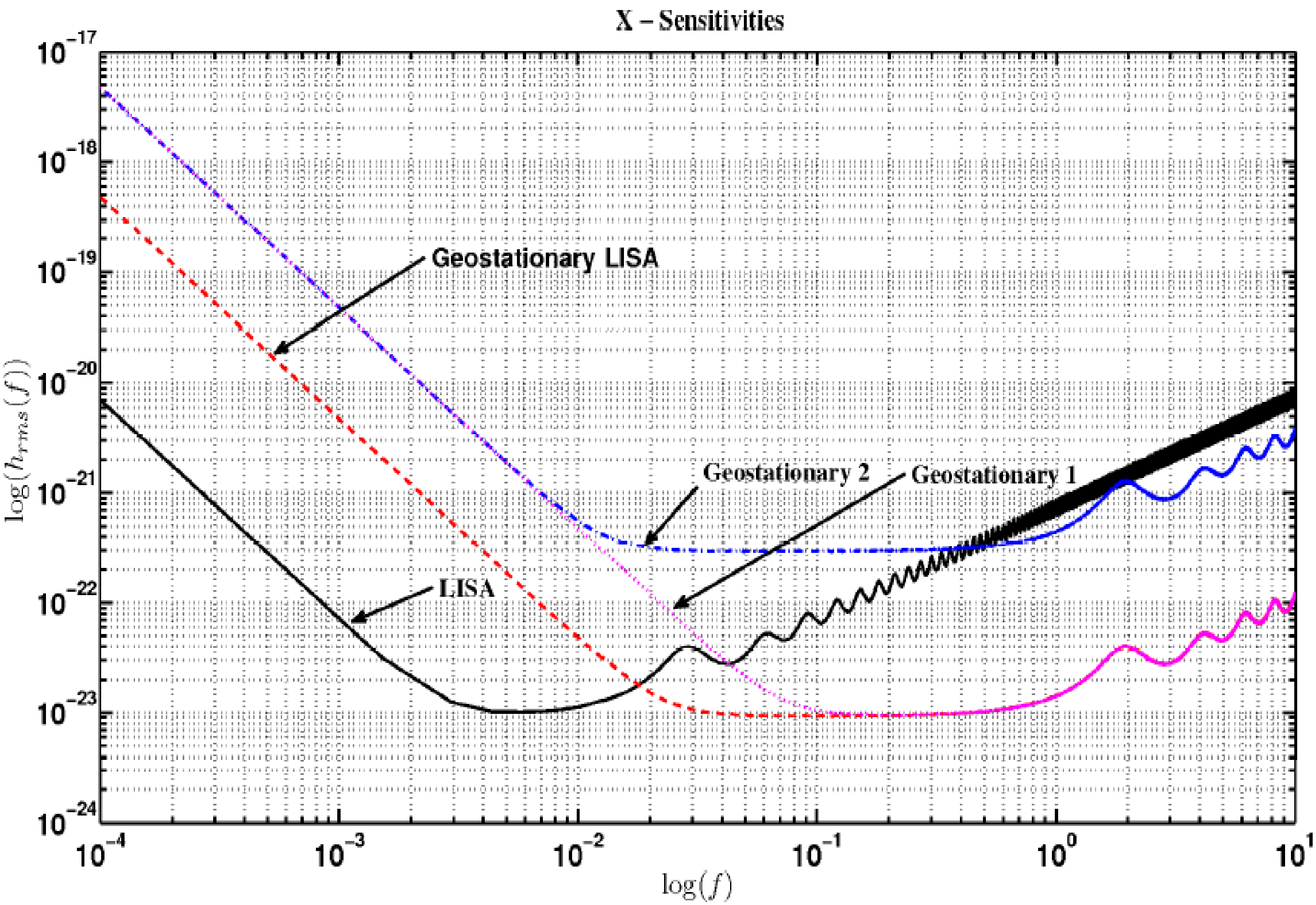
Mission Design and Orbit

- GEOGRAWI entails three spacecraft in geostationary (equatorial) orbit, forming an equilateral triangle with arm length of about 73,000 km.
- The main advantage of such an interferometer over LISA is that it is significantly less expensive to launch and position it in its final orbit.
- Because of its smaller arm length, further instrument simplifications over that base-lined for LISA follow as additional benefits.
  - no laser ranging modulations nor modulations needed by the Ultra-Stable Oscillator noise cancellation scheme will be required;
  - no articulation of the optical telescopes onboard each spacecraft will need to be implemented;
  - the attitude control subsystem and onboard propulsion units will be down-scaled accordingly to the less stringent needs imposed by the spacecraft trajectories;
  - ground data acquisition can be performed with three small dedicated antennas whose cost is a fraction of the tracking costs LISA would require;
  - in the eventuality of system/subsystem failure a robotic repair mission could be performed.

Sensitivities

- We have analyzed three different instrument configurations, which we refer to as:
  - **Geostationary LISA** (same onboard instrument configuration as LISA)
  - **Geostationary 1** (the output power of the onboard lasers and the size of the optical telescopes are assumed to be equal to those of the LISA mission, while the noise performance of the accelerometers is taken to be 10 times worse than that of the LISA accelerometer)
  - **Geostationary 2** (the noise performance of the accelerometers is taken to be 10 times worse than that of the LISA accelerometer, the output power of the lasers is assumed to be a factor of 10 smaller than that of the lasers onboard LISA, and the diameter of the optical telescopes has been reduced by a factor of $10^{1/2}$over that of the LISA telescopes.
- Our sensitivities calculations are based on the fundamental noise limitations of a space-based interferometer:
  - proof-mass
  - photon counting statistics.
- This is because some of the additional noises are expected to scale down linearly with the arm length, while some others should result into an overall contribution smaller than the proof-mass and photon-shot noises.
- A detailed/quantitative analysis will follow shortly!

Sensitivities (Cont.)



Science with GEOGRAWI

- The scientific advantages of a smaller arm length interferometer in space have already been discussed in the literature (see Schutz, Class. Quantum Grav. **18** (2001) 4145–4152).
- Since the sensitivity of GEOGRAWI at frequencies larger than about 20 mHz is significantly better that that of LISA, it will be able to observe:
  - Massive and super-massive Black Holes (SMBHs);
  - Stellar-mass binary systems;
  - Several binary systems present in our own galaxy (the so called “calibrators")
  - Cosmic strings;
  - A stochastic background of astrophysical or cosmological origin.

Science…(cont.)

- GEOGRAWI, like LISA, will perform a complicated rotational motion around the Sun, which will result into a periodic modulation of any anisotropic background of gravitational radiation.
- Although GEOGRAWI will be unable to detect the zero-order cyclic spectrum of the white dwarf-white dwarf galactic binary confusion noise, it will however detect and measure the higher-order “cyclic spectra" present in the data because these are not affected by a stationary instrumental noise. (J.A. Edlund, M. Tinto, A. Krolak, G. Nelemans, *Classic.Quantum Grav.*, **22**, S913-S926 (2005))

Science…(cont.)

- We have recently analyzed (J.C.N. de Araujo, O.D. Aguiar, M.E.S. Alves and M. Tinto, gr-qc xxxx) how well and how many SMBH GEOGRAWI will be able to detect, as these sources were of primary interest to LISA.
- Since a significant amount of GW energy can be released during the three evolutionary phases (inspiral, merger and ring-down) of these systems, we have calculated the maximum redshift, for a given SNR, at which these systems could be detectable during these three phases.
- From these results we then inferred the event rate by relying on a model of the formation and evolution of massive and super massive black-holes.
- We found that the Geostationary LISA configuration could see as many as 19 black-hole binaries per year with a SNR = 10 out to a maximum redshift of 10. This number of events rate is slightly larger than that for LISA as a consequence of GEOGRAWI better sensitivity at higher frequencies where smaller black-holes binaries radiate.
- Since smaller BHs are easier to form and are therefore larger in number than larger BHs, a geostationary LISA will be able to see more of them than LISA.

Costs

- The main cost saving factors w.r.t. LISA have been identified to be:

Launch Services	(-\$M 183)	
GRS (6 -> 3)	(-\$M 160)	
Spacecraft	(-\$M 143)	(B)
Propulsion Module	(-\$M 54)	(B)
Ground data systems	(-\$M 53)	(B)
Mission Operations	(-\$M 50)	(B)

- We estimated a total mission cost of ~ \$M 1,100.
- A partnership with the Brazilian Space Agency would reduce the US cost down to ~ \$M 940.

Q&A

- Q: *Which of the three concepts should we study? Your RFI response seems to favor Geostationary LISA.*
- A: Of the three GEOGRAWI configurations considered, we propose to focus the study effort on the Geostationary LISA.

- Q: *This concept is very similar to that proposed by McWilliams with the possible exception of the GRS design. Do you have any objections to us treating these concepts as one?*
- A: We do not have any objections to treat the two concepts as one.

Q&A (Cont.)

- Q: *The LISA displacement noise budget includes terms other than shot noise such as optical path noise in the telescope and optical bench, pointing noise, phase meter noise, etc. Together these terms make up a significant fraction of the total. How should we treat these terms?*
- A: Some of the additional noises are expected to scale down linearly with the arm length, while some others should result into an overall contribution smaller than the proof-mass and photon-shot noises. A more detailed/quantitative analysis will follow shortly!

- Q: *Have you planned for propulsion for disposal at End-of-Life?*
- A: The short answer is no. However, we believe that this should not result into a significant increase of the allocated mission budget because of the simplicity of the required maneuver.

Q&A (Cont.)

- Q: *Is the spherical proof mass an essential part of your concept?*
- A: We opted for a single spherical proof-mass in order to further simplify the onboard instrumentation and for cost reduction. If cost could be reduced (without affecting performance) by relying on an alternative drag-free subsystems, this could be incorporated into the GEOGRAWI design.