

Deci-hertz Interferometer Space Antenna

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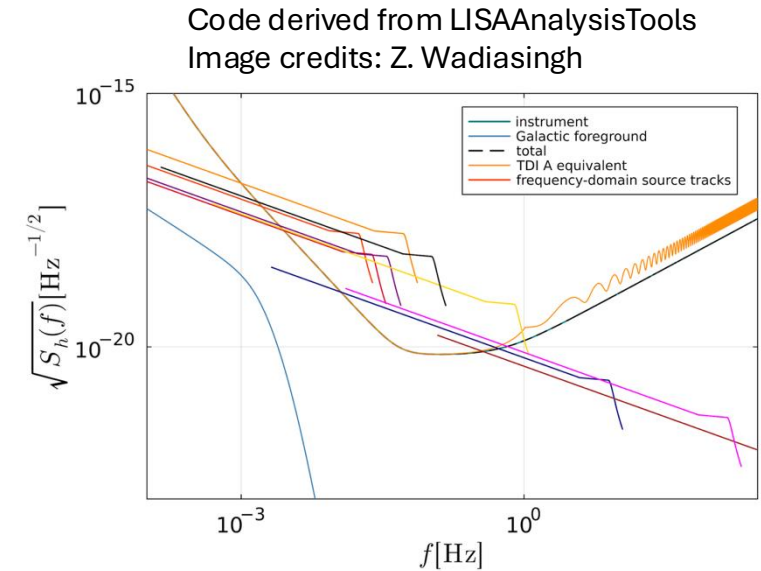
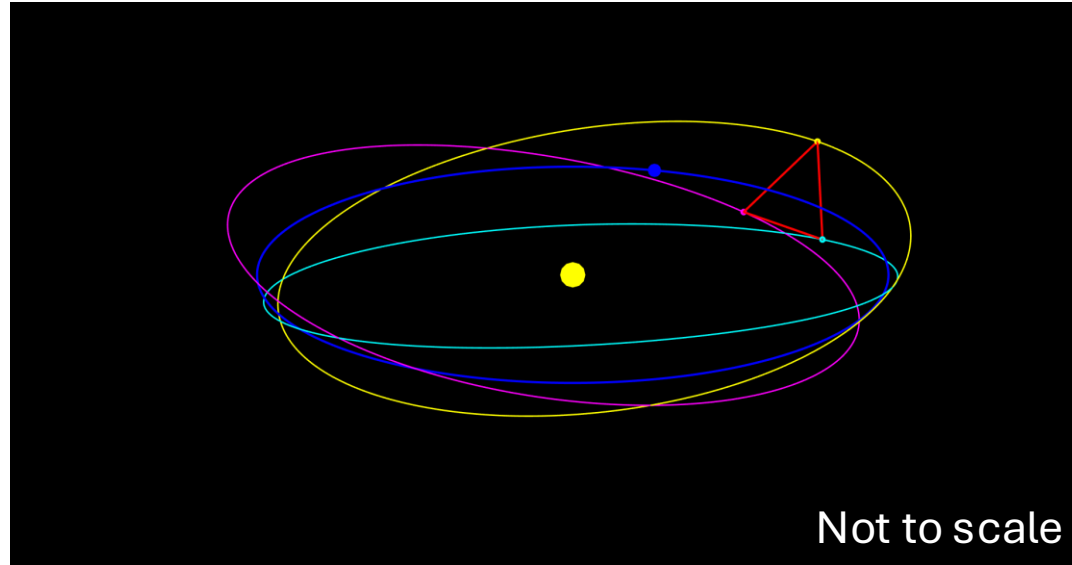
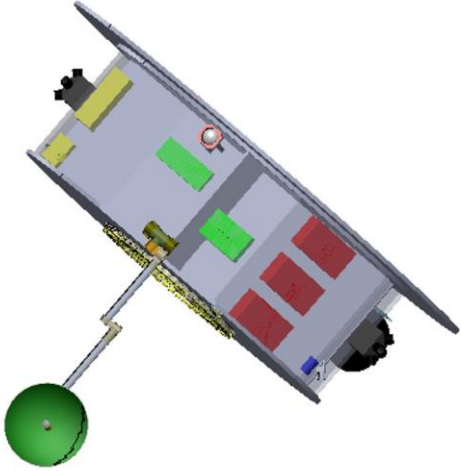
Mission Design Philosophy

To ruthlessly pursue scientific knowledge, we will exploit technological advances fully before advancing new ground-breaking technology development. Be the first, not the final, word.

Where-ever possible, use commercially available components or fixed-price follow on orders to existing hardware development and delivery contracts. In this case, apply technology from LISA, GRATTIS (ESTO mission, launch NET27), GRACE FO, etc...

Accept risk (Class C) up front, minimize redundancy in hardware and testing. The metric is time to science, given a budget.

MISSION CONCEPT



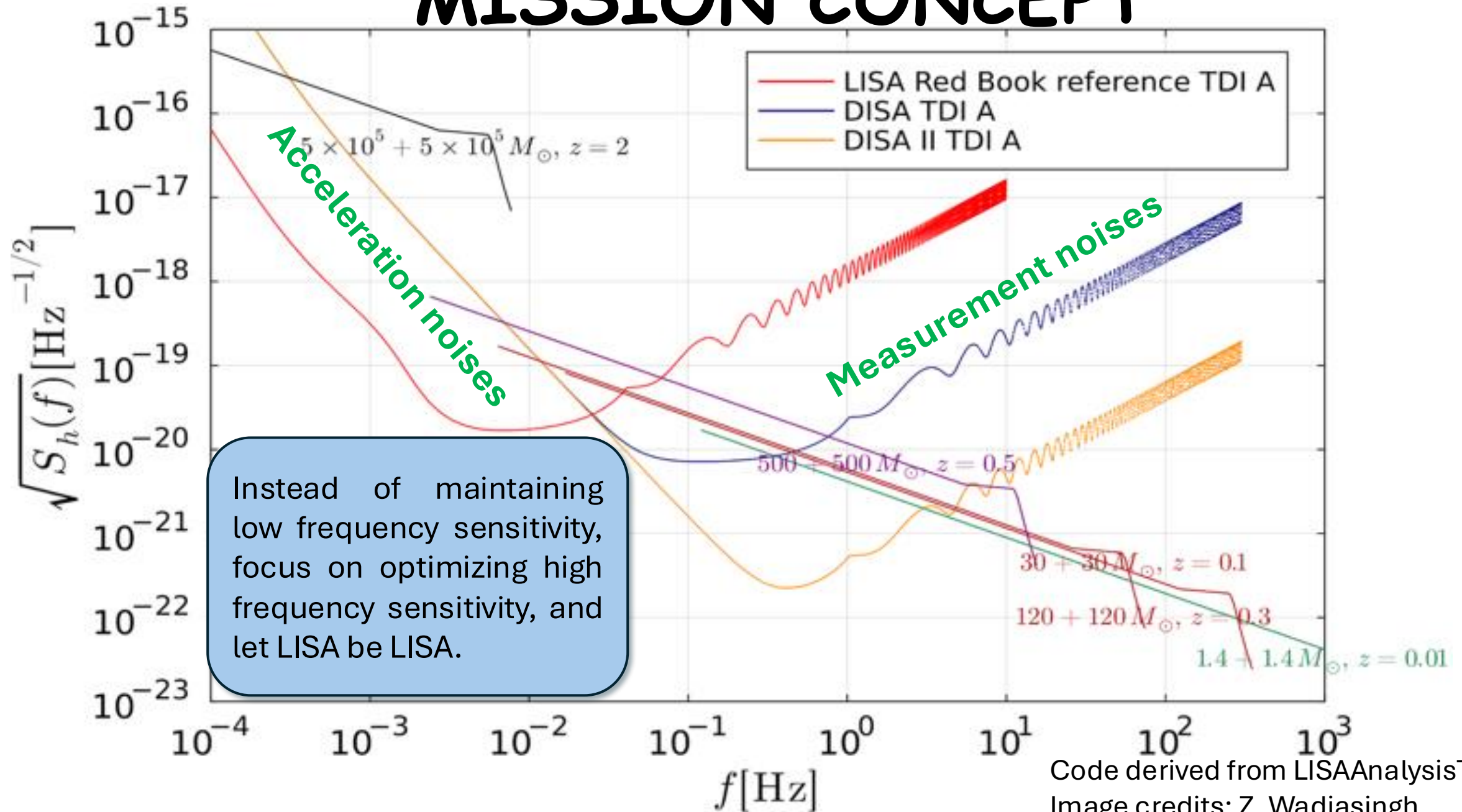
Target the dHz band by shrinking inter-spacecraft spacing from 2.5Gm to 100Mm, increasing laser power.

Aim for lighter sources than LISA, at higher frequency.

Derive instrument requirements, especially deviations from LISA

To obtain preliminary point design of spacecraft, science orbits, launch and transfer options, science mode propulsion, communications, science operations, and cost we carried out a Mission Design Laboratory study at Goddard Space Flight Center.

MISSION CONCEPT



Code derived from LISAAAnalysisTools
Image credits: Z. Wadiasingh

Armlength and Frequency Bands

We measure strain $\delta L/L$ across our interferometric observatory due to gravitational waves. δL is measurement precisions, L is arm length.

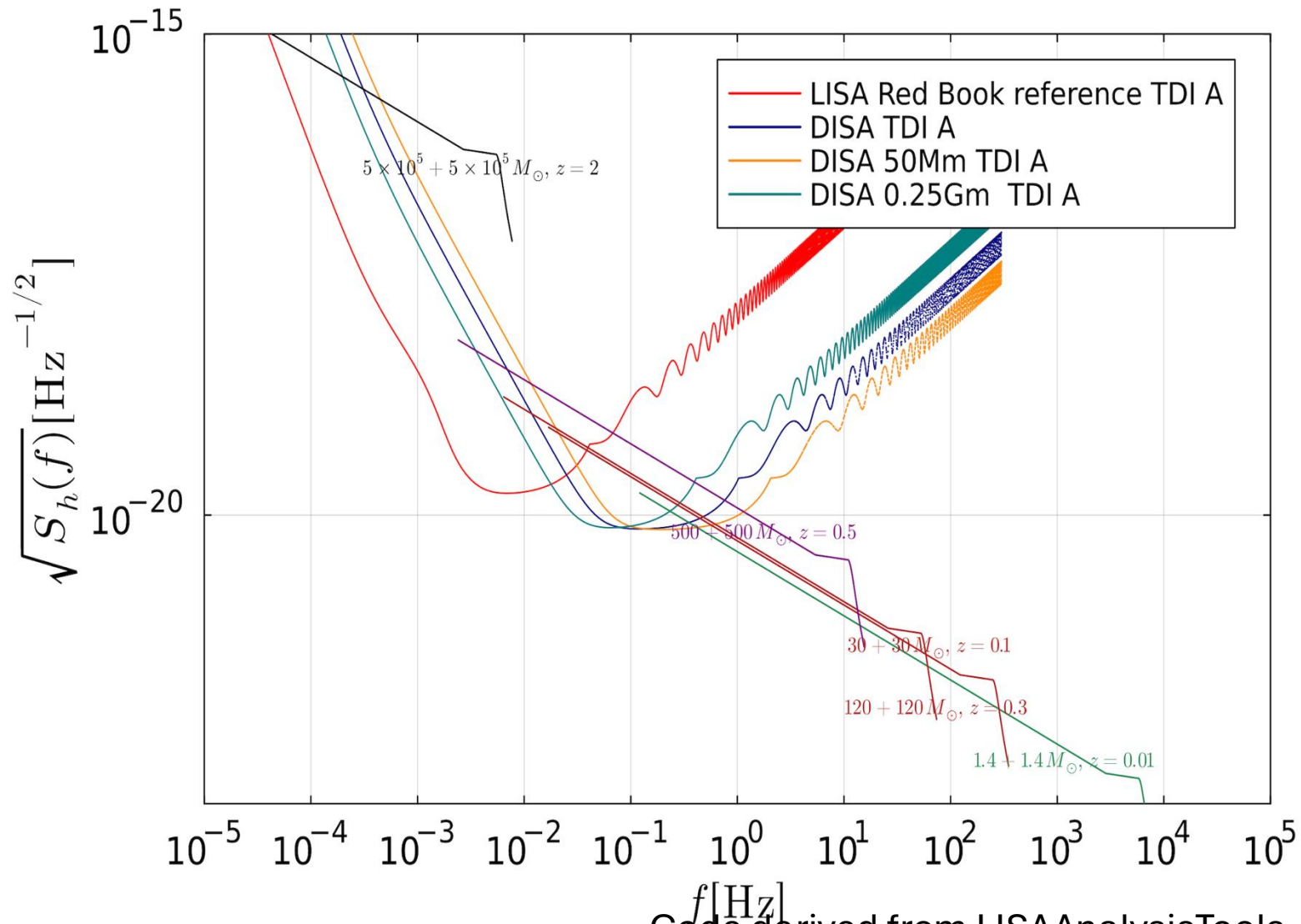
Finite armlengths divide the sensitivity

$$\text{response by } \sim 1 + \left(\frac{f}{C_0 * f_0} \right)^2,$$

$$\text{where } f_0 = \frac{c}{2L} \text{ and } C_0 \sim 0.41$$

Sensitivity loss due to shrinking L cancels with improving δL wherever photon shot noise dominates sensitivity, as received power goes like $\frac{1}{L^2}$.

Larger arms make measurement quadratically more difficult at high frequency!

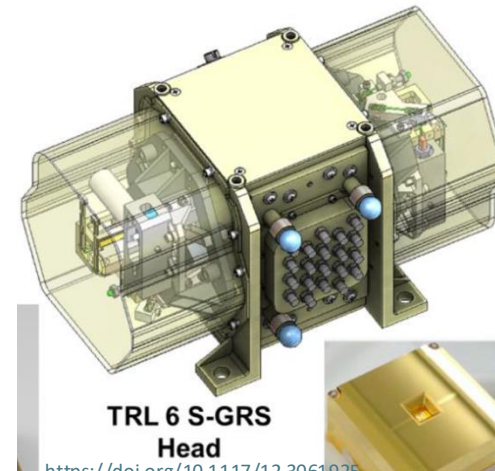


Code derived from LISAAAnalysisTools
Image credits: Z. Wadiasingh

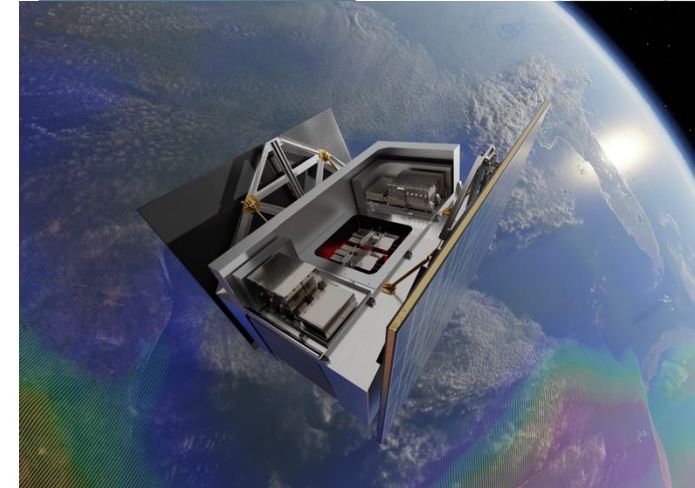
Instrument sources and performance

Assumptions used for point design of DISA:

- Simplified Gravitational Reference System (SGRS) available from UF and affordable.
- LISA laser and telescope progressing well, cost savings available buying further units. Assumed notional amplification stage added to laser to reach 10W.
- Phasemeters (JPL, UofA) and optical bench technology (UF, UofA) exists domestically at medium TRL. LISA requirements drivers such as inter-spacecraft Doppler rate are improved in DISA the mission design, which combined with higher frequency operation allows increased sensitivity.



<https://doi.org/10.1117/12.3061925>

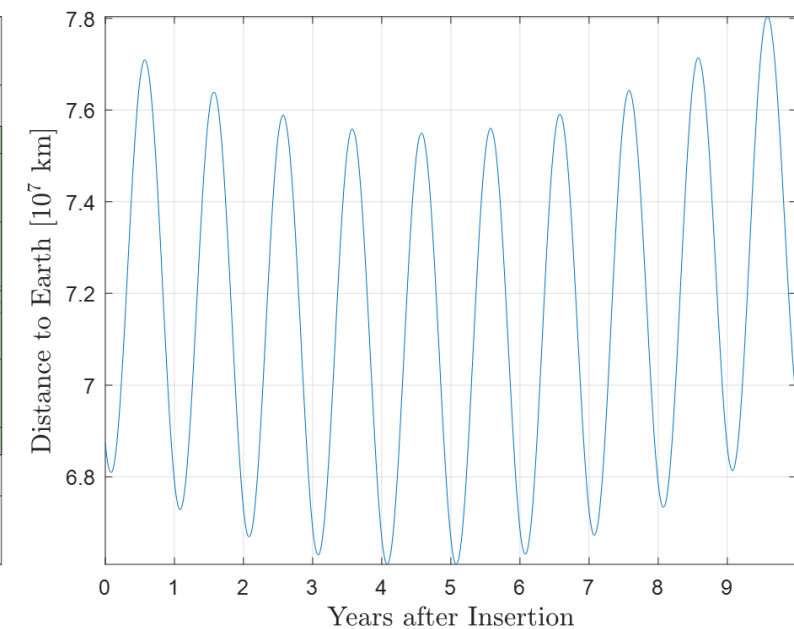
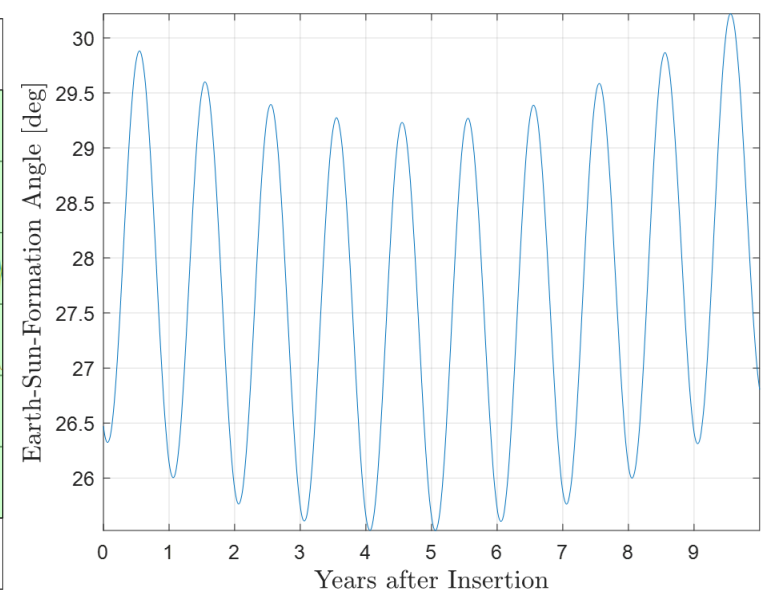
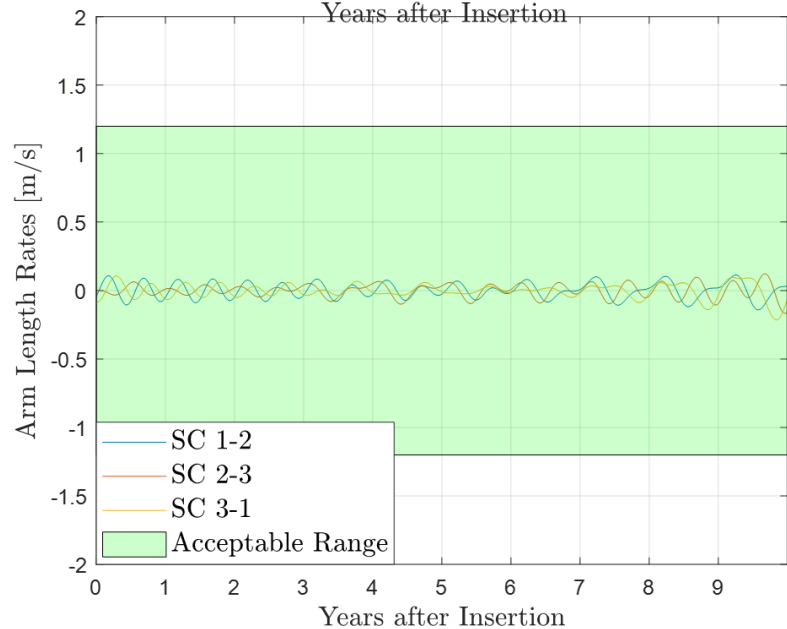
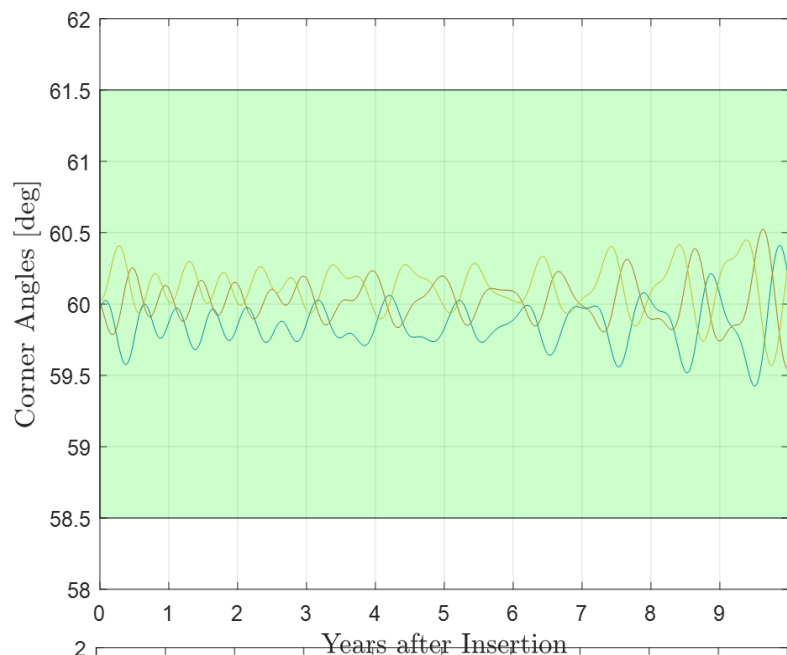


Orbits and Communications

Science team found LISA communications budget reaching 1 Hz sufficient for 99% of SNR, compared to notional 10 Hz bandwidth.

Moved constellation away from Earth to improve orbital stability, which reduces requirements on the phasemeter.

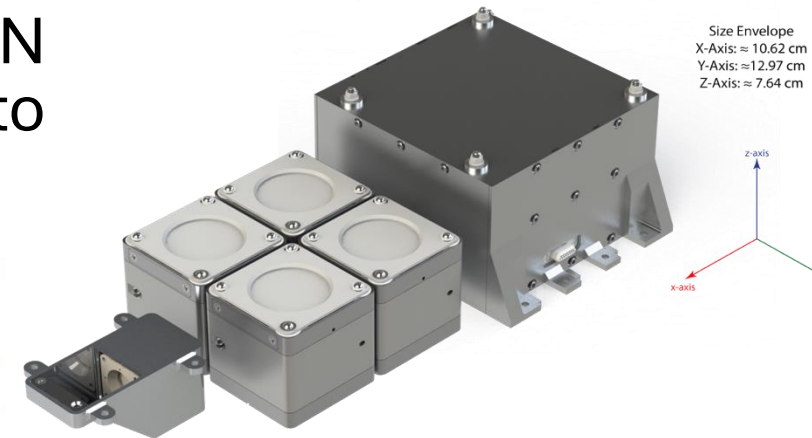
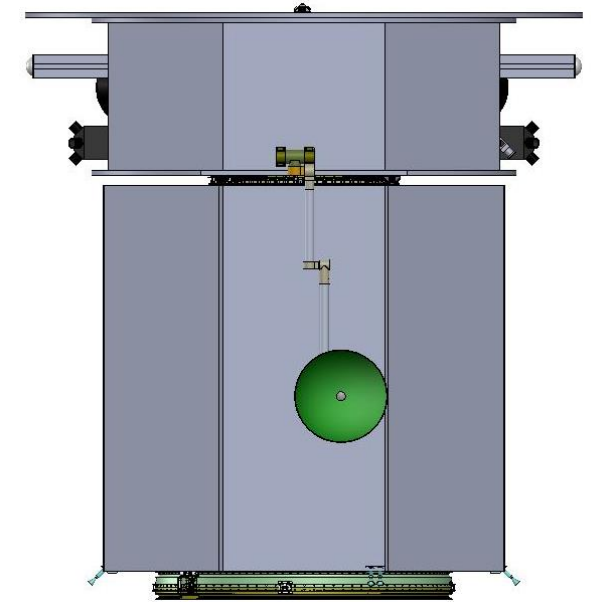
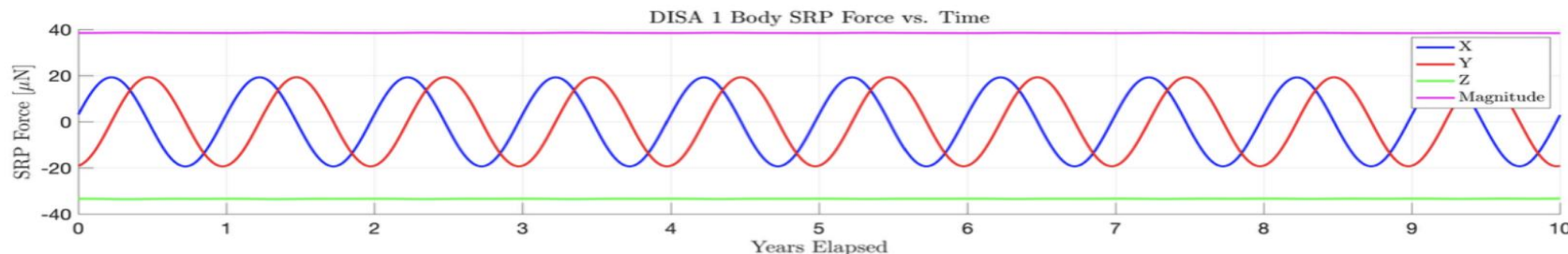
Solved for essentially the same 0.5m dish as LISA independently based on data budget.



In-Space Propulsion

Transfer could use SEP or chemical, chemical requires separable propulsion module. EP requires more solar panels, structure, micro-propulsion to counter increased solar pressure, and an extra 6 months of transit. Chemical requires additional care for science orbit insertion.

Science operations use electrospray micro-propulsion. Need $39 \mu\text{N}$ to counteract solar pressure, much smaller amounts for drag free control, estimated $\sim 18 \text{ kNs}$ per spacecraft with margin. Busek BET-MAX thruster derived from LISA Pathfinder, thrust range <1 to $100 \mu\text{N}$, $<1 \mu\text{N}$ precision, small size, highly mass efficient. Potential to distribute around SC to maximize efficiency over orbit

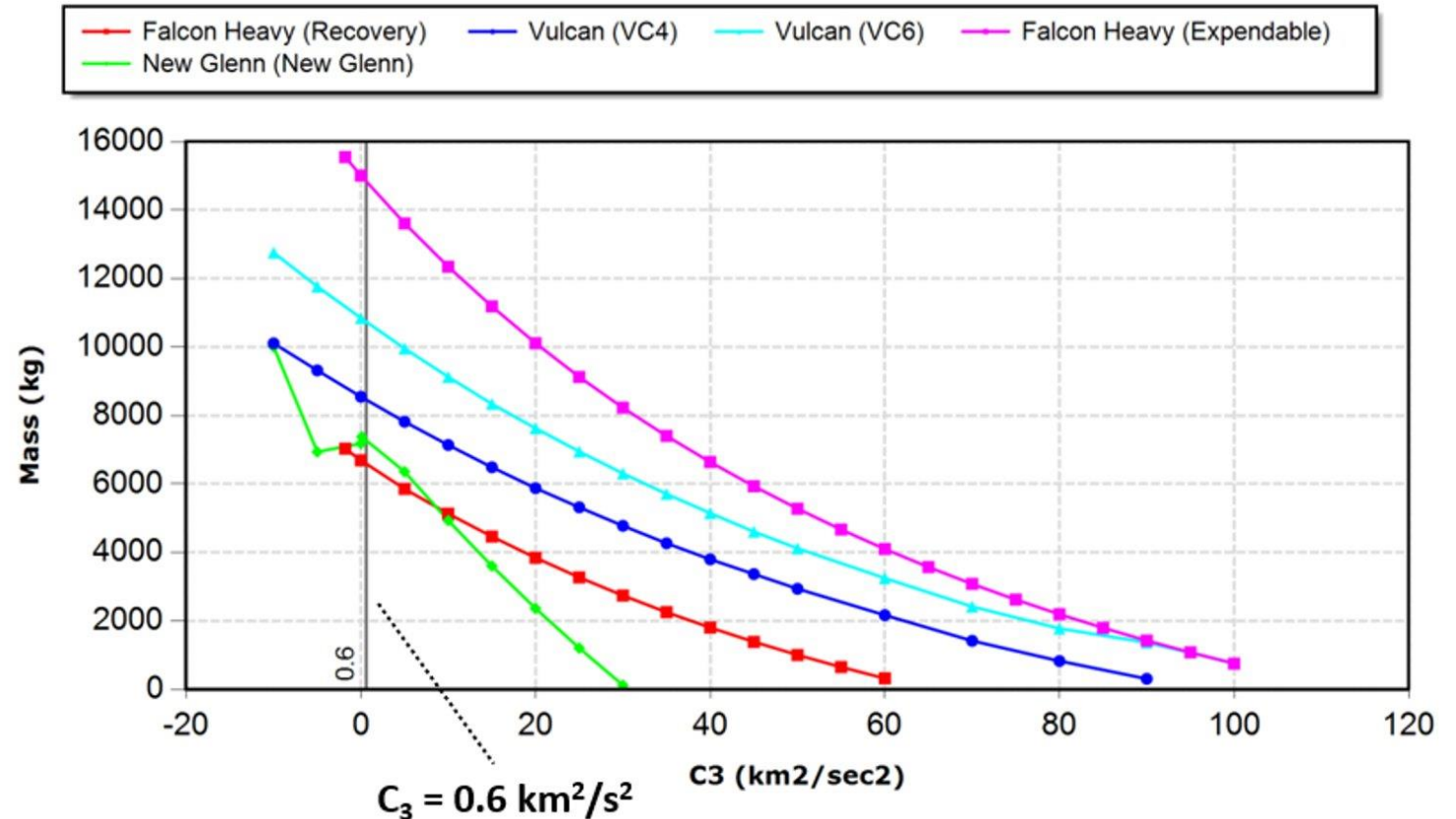


<https://www.busek.com/bet-300p>

Launch Options

Based on DISA mass estimates and mildly positive C_3 (escape)

Depending on mass of propulsion module, several existing launchers have the needed capacity. No need to “choose” at this time.



Costs and outlook

- Mission elements including hardware production costs O(\$200M)
- MDL estimates other costs and margin via multipliers on top of the hardware based on mission class, also applied to payload costs when provided.
- In this configuration, it would be challenging to fit in a MIDE box, with O(\$500M) total mission cost, ***but easily within a Probe budget.***
- The MDL costing was entirely parametric, despite identifying real subcomponents in most cases, with only the mechanical bus itself bespoke. No off the shelf buses were available for analysis, but regardless would require modification to be used drag free.
- Given the parameters of Ad ASTRA, **we proposed pushing aggressively on payload performance in white paper.**

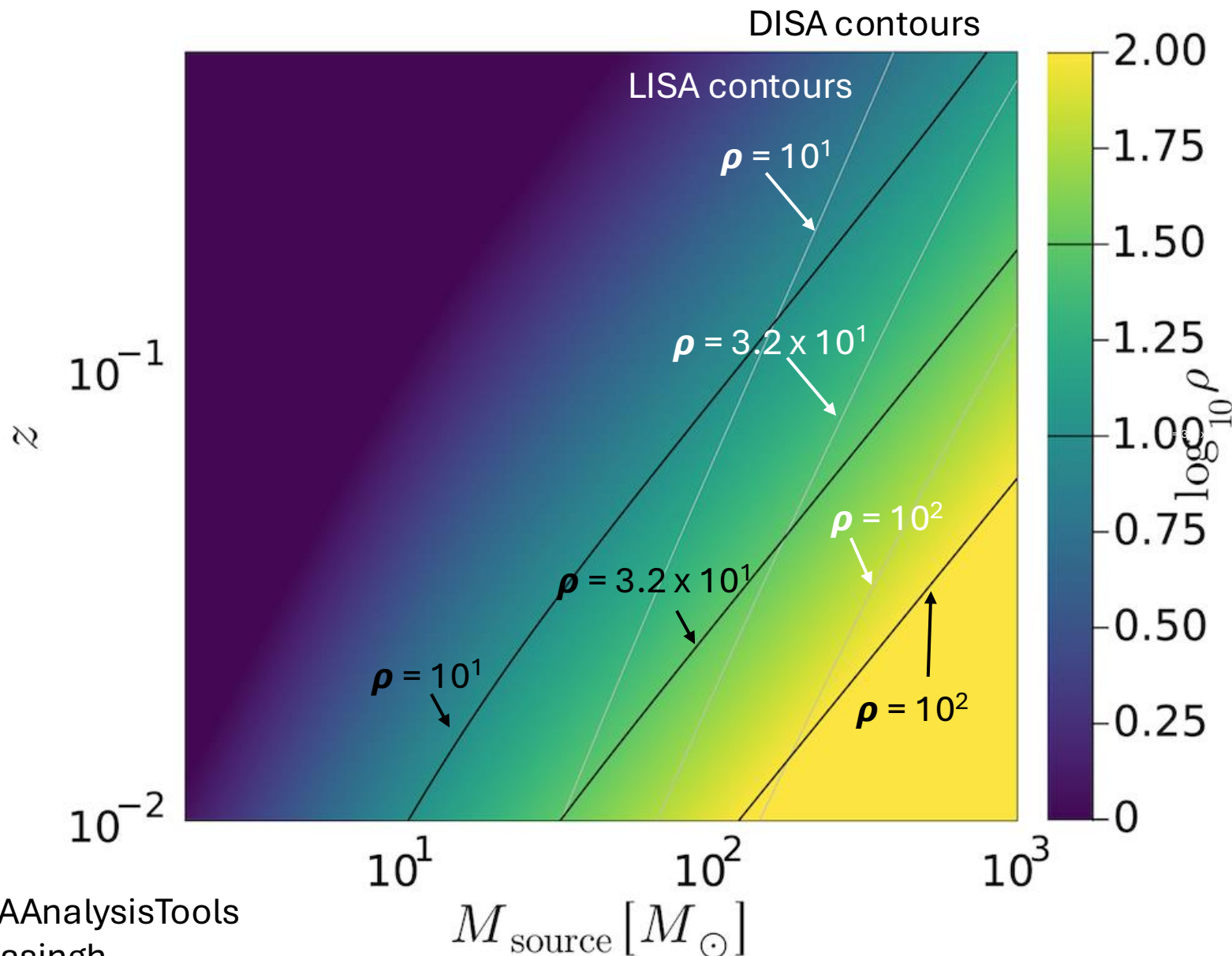
DISA Science Performance

Rates estimated using LVK
GWTC-3 Catalog, 3 yr mission
lifetime

Binary Neutron Star Mergers:
up to a few low SNR events

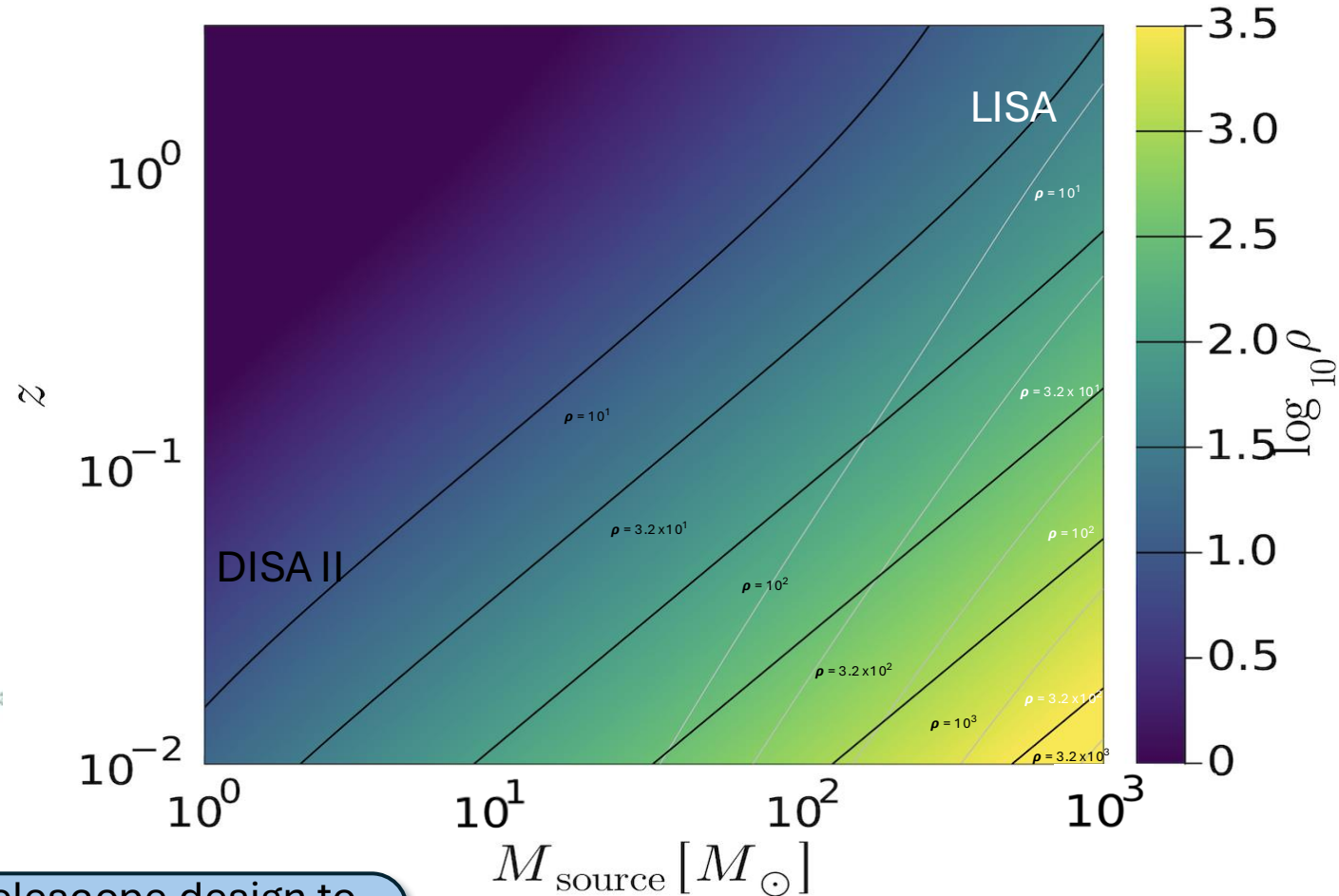
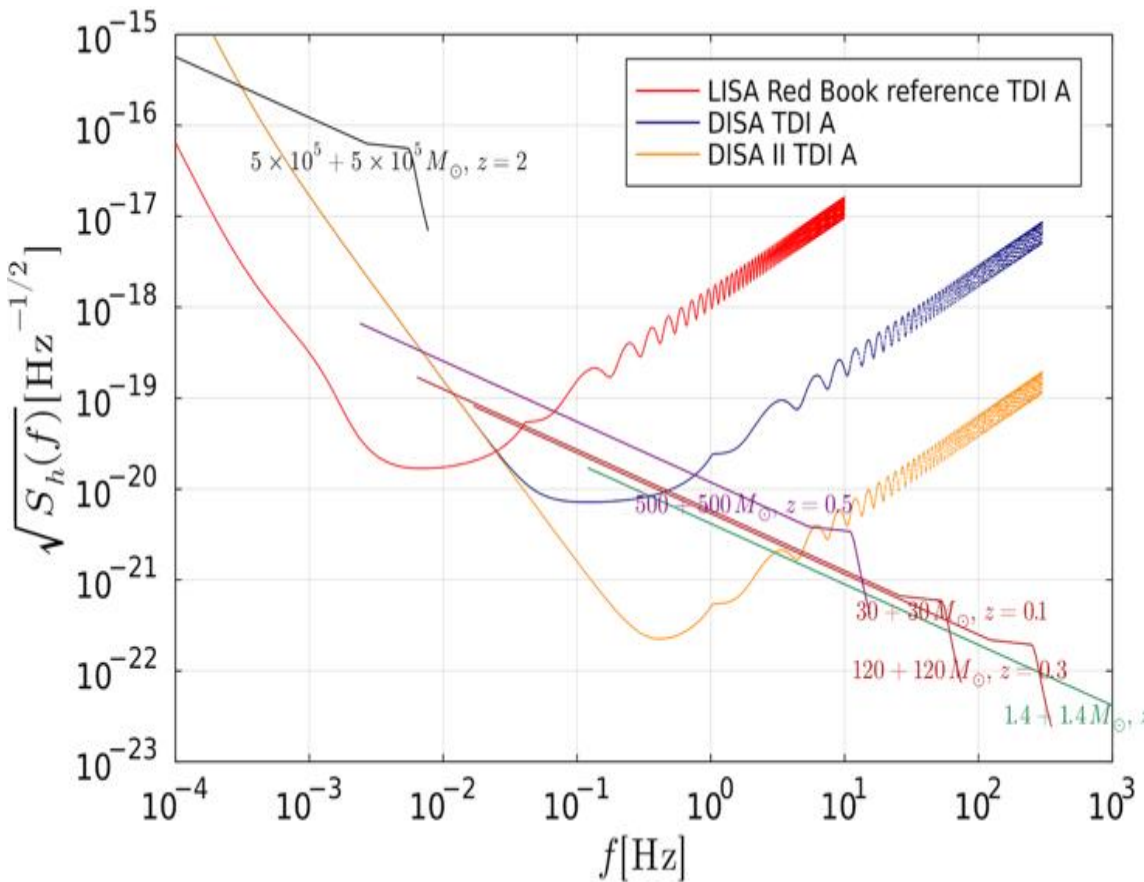
Binary Black Hole mergers:
tens of sources, moderate
SNR

Neutron Star Black Hole
Merger: maybe 1?



Code derived from LISAAAnalysisTools
Image credits: Z. Wadiasingh

Enhanced DISA Science Performance



We proposed improvements in laser power and telescope design to take full advantage of increased metrology performance. Increased optical sensitivity significantly improves merger rates, including significant BNS potential and excellent BNS localization.

Code derived from LISAAanalysisTools
Image credits: Z. Wadiasingh

Thank you, I am happy to take your questions

- Contributions to studying DISA and dHz science:
 - John Baker
 - Zorawar Wadiasingh
 - Scott Noble
 - Vera DelFavero
 - Konstantinos Kalapotharakos
- Other technical contributions
 - GSFC MDL
 - Gabriel Freedman (GSFC)
 - Nate Demmons (Busek)
 - John Conklin and Peter Wass (University of Florida)
 - Felipe Guzman (University of Arizona)