RFI Group 2: Geocentric Mission Concepts

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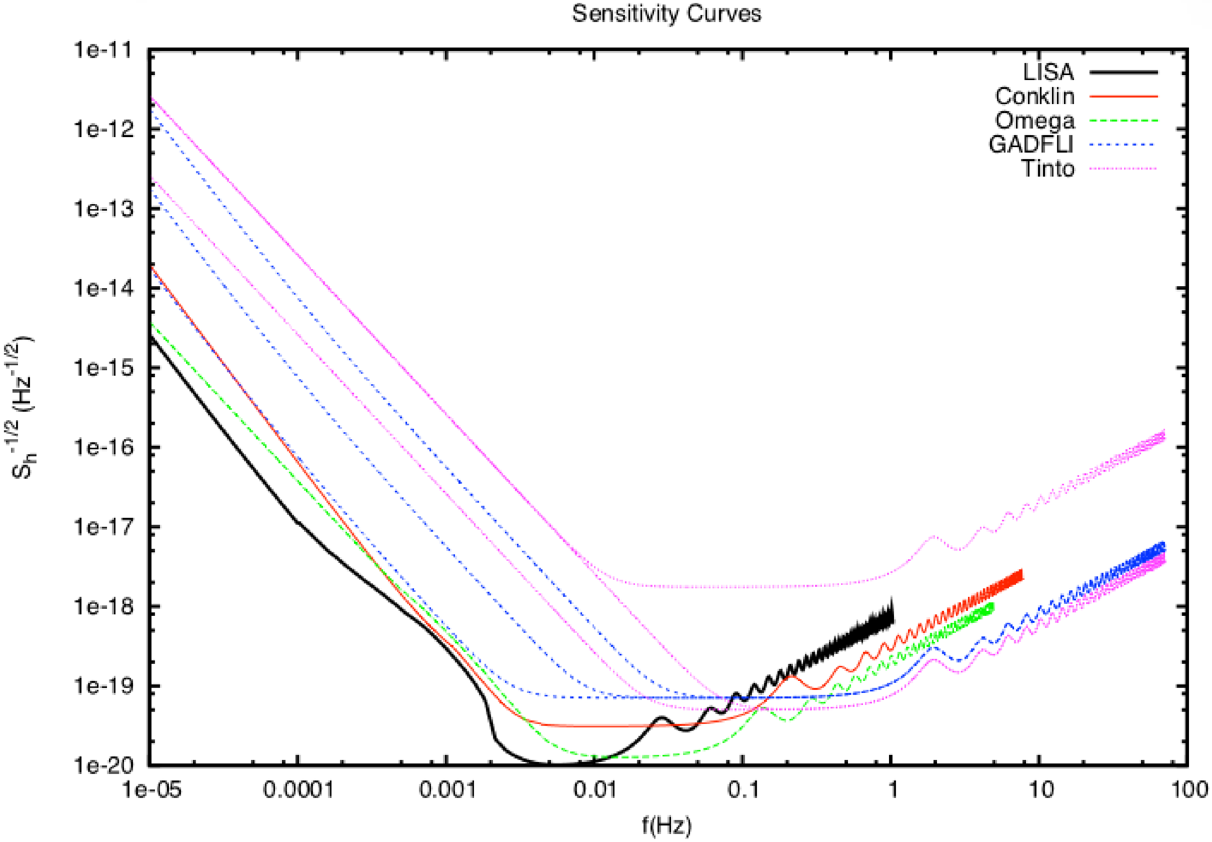
Group 2 Mission Concepts

Acronym	Lead Author	Concept	Arm Length (Mkm)	Duration (yrs)	# alternates
GEOGRAWI	Tinto	Triangle from 3 geostationary SC, spherical proof mass	0.07	2?	3
GADFLI	McWilliams	Triangle from 3 geostationary SC	0.07	2	3
OMEGA	Hellings	6 micro-SC in 600,000km Earth-Moon orbit	1.04	3	1
LAGRANGE	Conklin	3 SC in Earth-Moon L3,L4,L5 Single optical bench, spherical proof mass	0.67	5	1

Sensitivity Curves



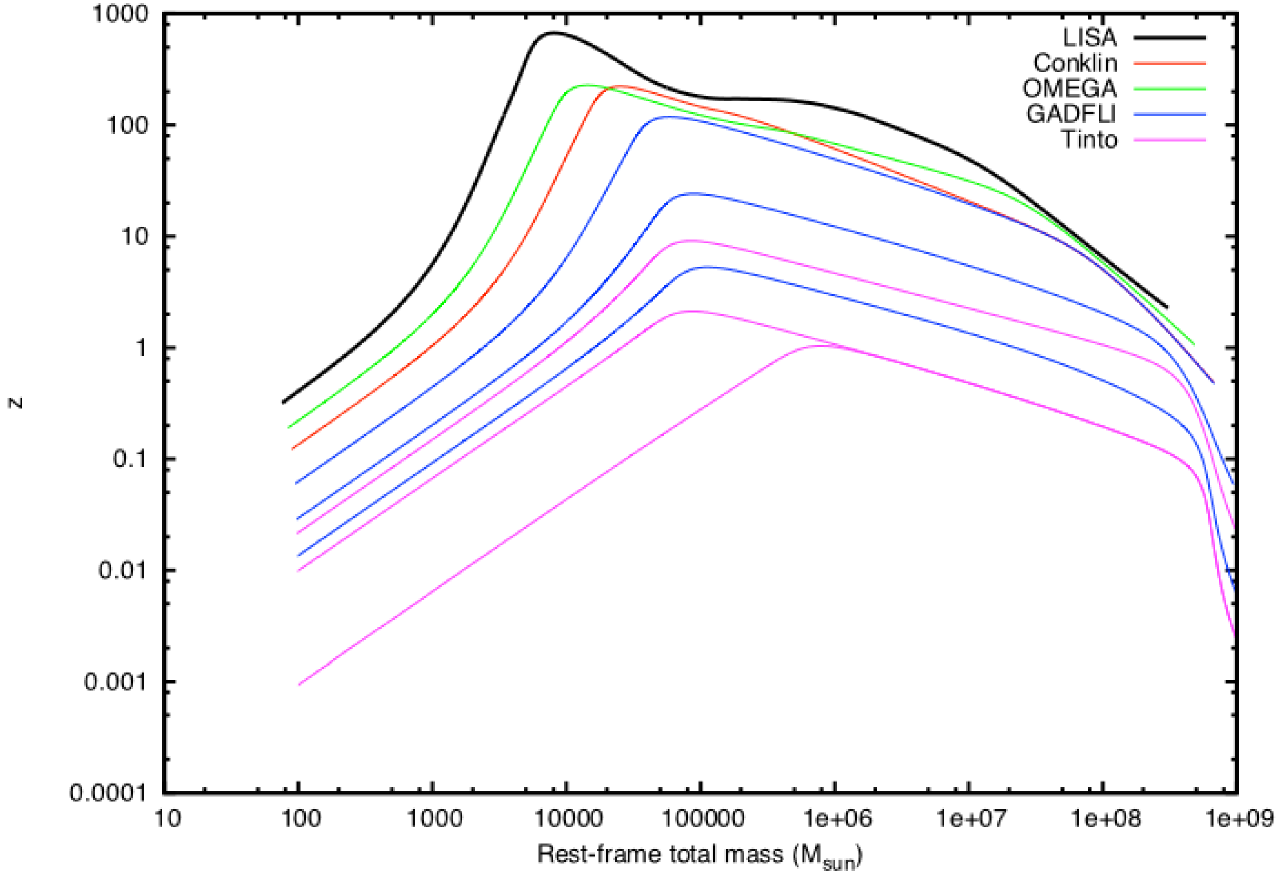
*NOTE: These curves are taken directly from the RFI. Ongoing attempts to reconcile them with calculated curves indicate their may be some significant discrepancies.

BH Science I

NWNH: ***Measurements of BH mass and spin will be important for understanding the significance of mergers in the building of galaxies.***

Horizon distance for BH waveforms:

- "PhenomC" waveforms (IMR, no higher harmonics)
- Mass ratio = 1:3, spin1 = spin2 = ½, SNR = 10

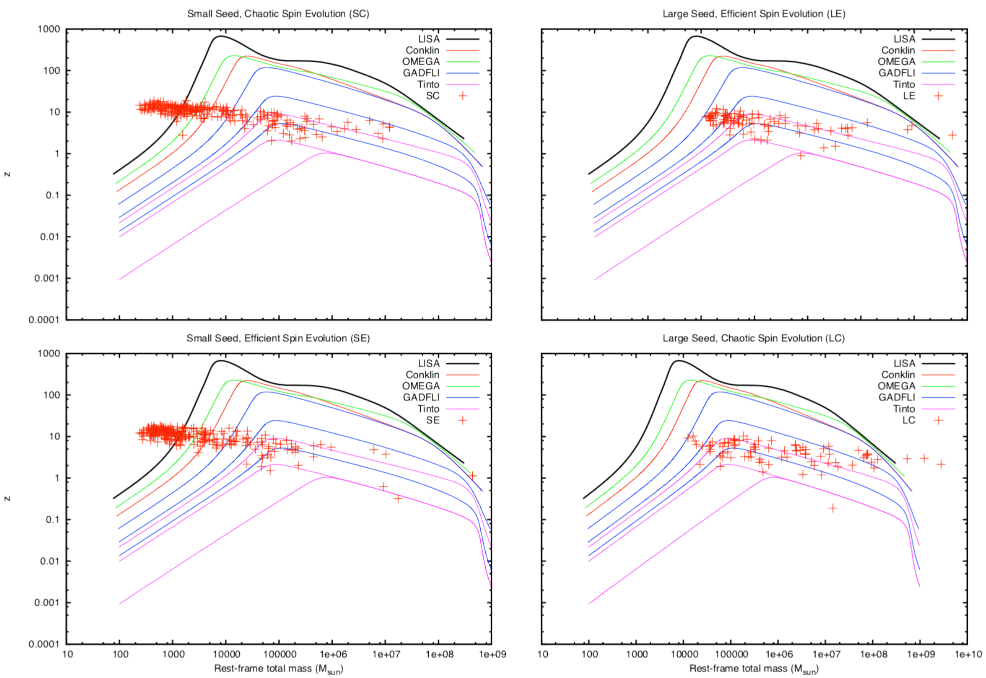


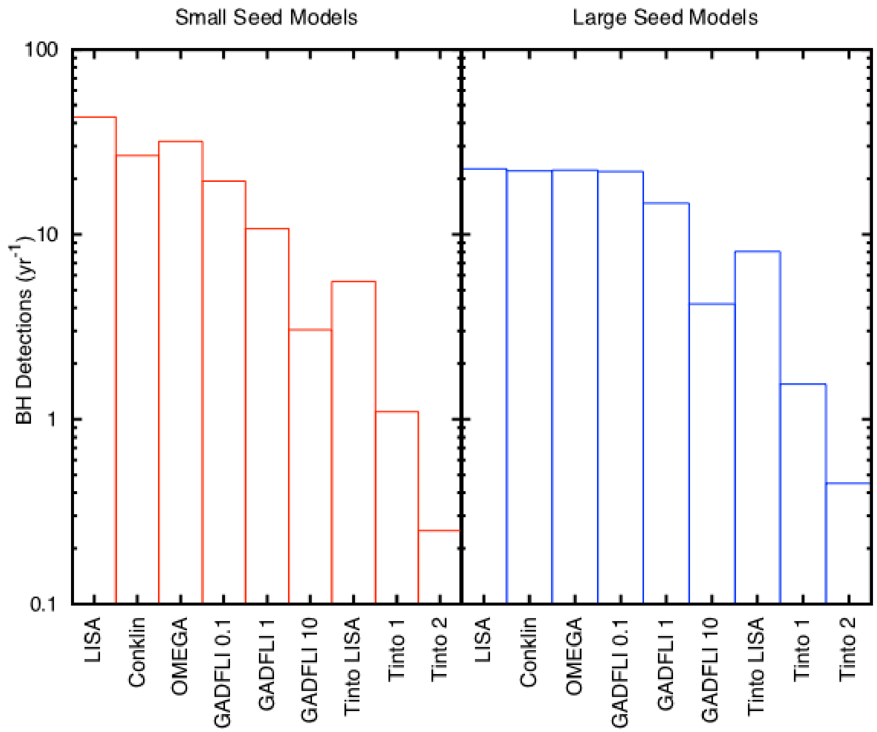
BH Science 2

NWNH: ***Measurements of BH mass and spin will be important for understanding the significance of mergers in the building of galaxies.***

BH Detection Rates

- Convolve horizon with population models (SC,SE,LC,LE)
- S = Small Seeds, L = Large Seeds, C = Chaotic Spin Evolution, E = Efficient Spin Evolution
- Detections "come with" precision measurements of **mass** and **spin**



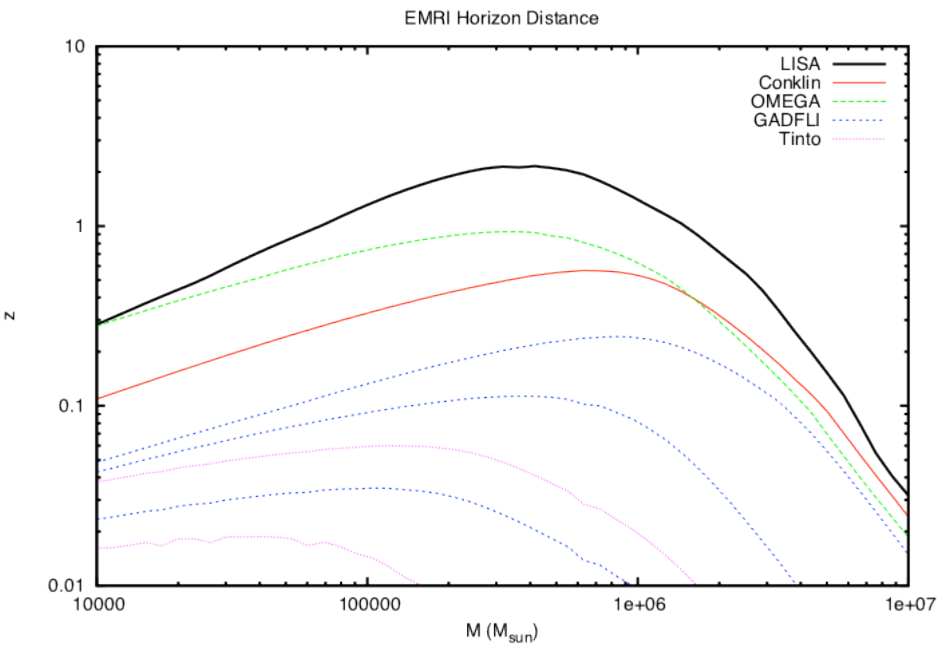


EMRI Science

NWNH: ***Detections of signals from EMRIs would provide exquisitely precise tests of Einstein's theory of gravity.***

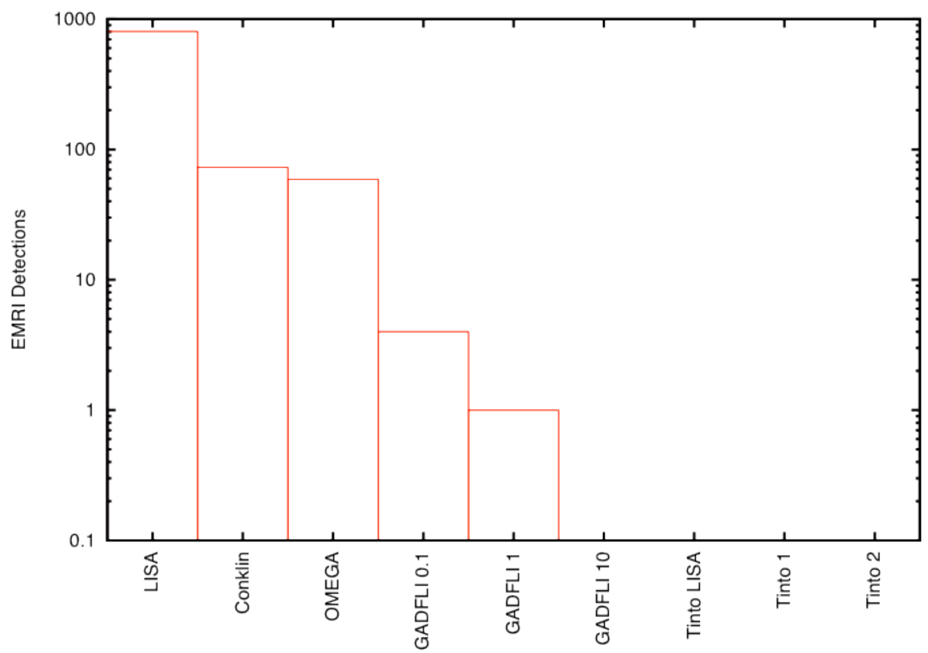
Horizon distance for EMRIs:

- Barack-Cutler waveforms
- 10 Msun compact object, eccentricity = 0.5, 2 years before plunge
- Central black hole with spin = ½, Threshold SNR = 15.



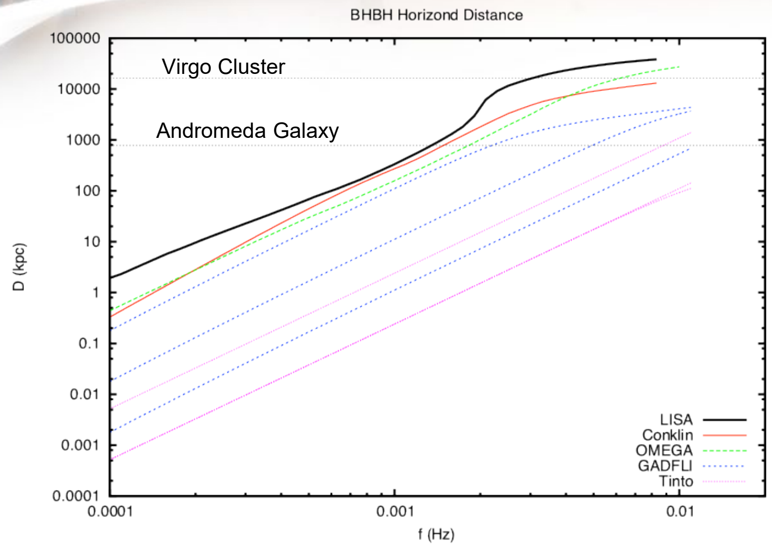
Total # of detections over mission lifetime:

- Observation times: 5 yrs (Conklin), 3 yrs (OMEGA), 2 yrs (GeoStationary)
- EMRI population a (conservative) variant of Class.Quant.Grav. 21 (2004) S1595-S1606

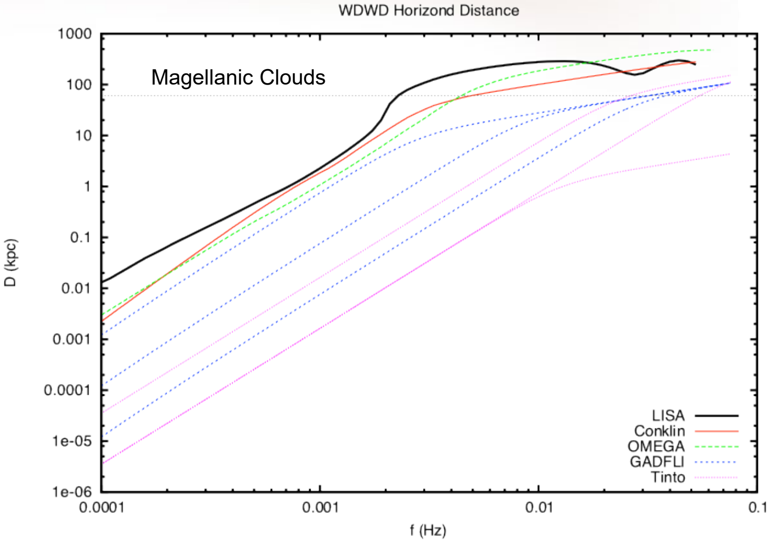


Galactic Binary Science

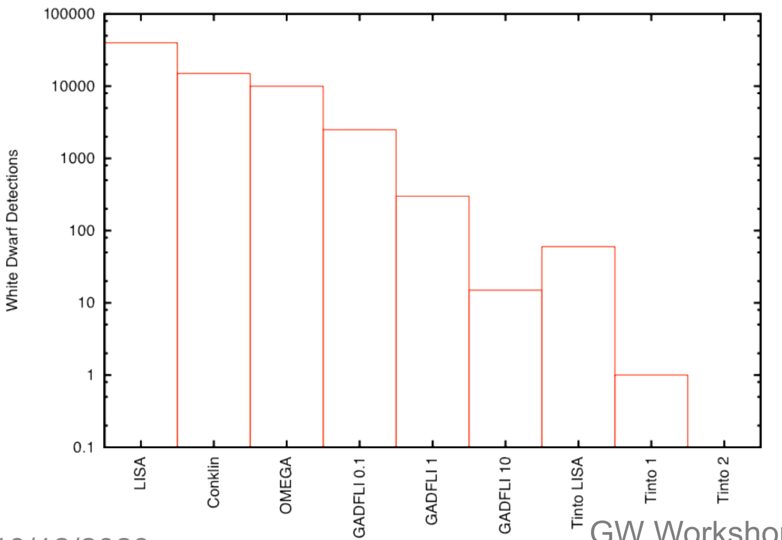
10 – 10 Msun Binary System, Threshold SNR = 7



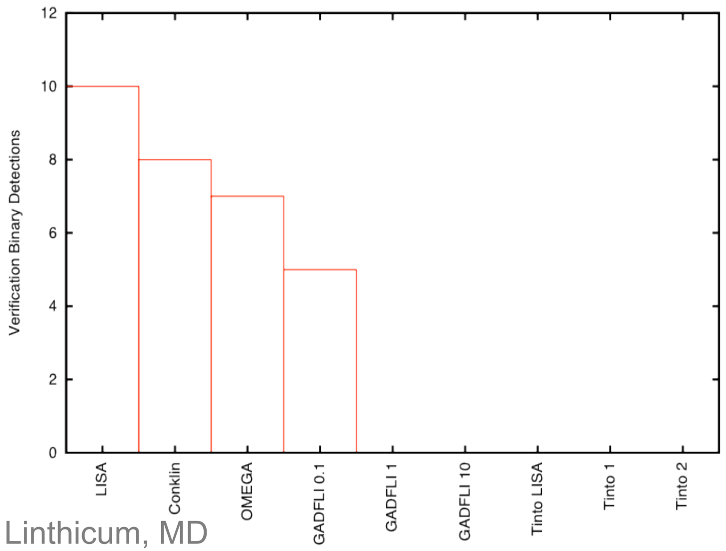
0.5 – 0.5 Msun Binary System, Threshold SNR = 7



WD-WD Detections from Nelemans Catalog



Number of known verification binaries w/ SNR > 7

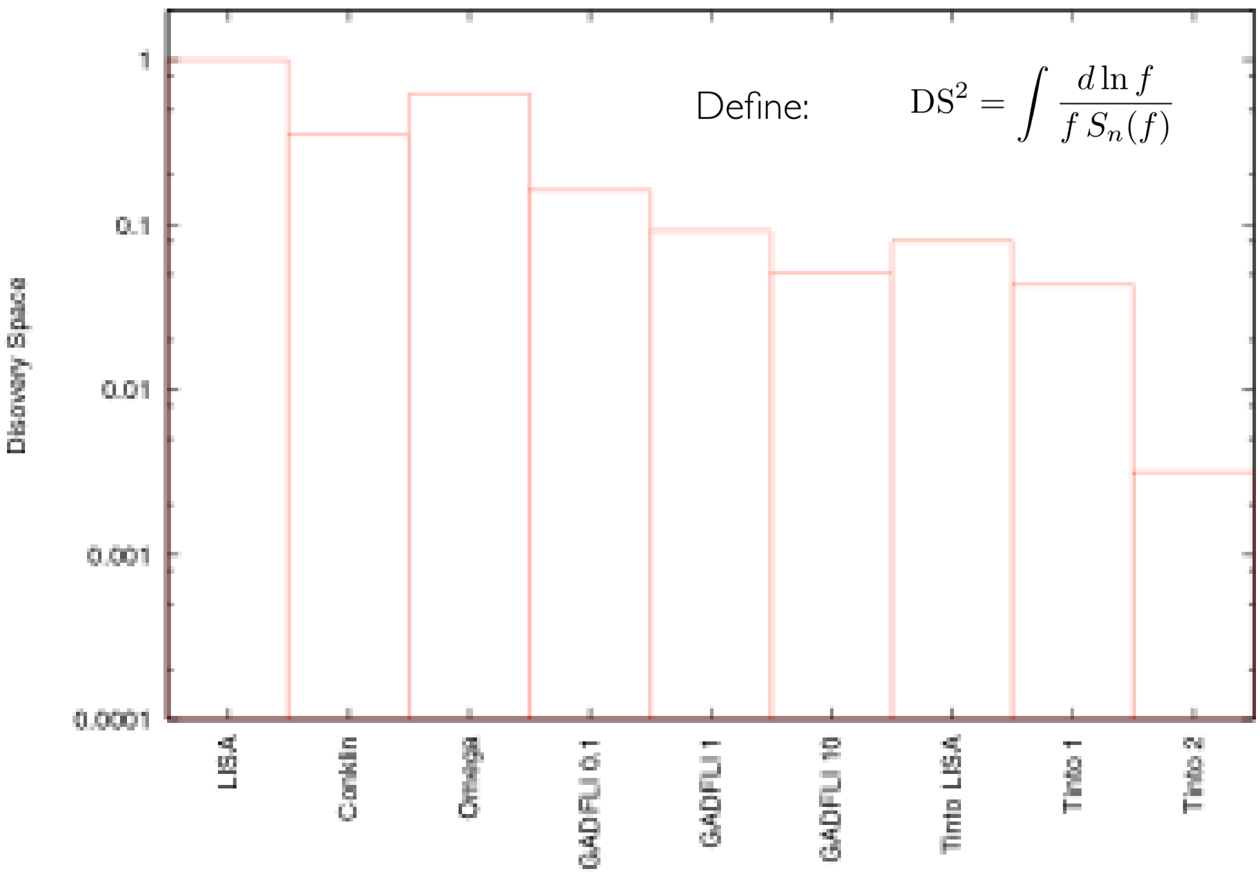


Discovery Space

NWNH: Potential for discovery of waves from unanticipated or exotic sources.

Discovery Space

- Measure of volume of signal space accessible to discover:
- Normalized by LISA volume



Science Summary

- **NWNH identified goals:**
  - All concepts will provide some information on mass & spin of MBH. Event rates are higher with OMEGA & LAGRANGE and higher SNR should also improve parameter estimation
  - OMEGA & LAGRANGE have high probability of detecting EMRIs. It is not likely GEOGRAWI or GADFLI will detect EMRIs.
  - OMEGA & LAGRANGE have a discovery volume 3-10x larger than GEOGRAWI or GADFLI
- **Other LISA Science (Galactic Binaries)**
  - All concepts detect compact binaries
  - No verification binaries with GEOGRAWI or GADFLI

OMEGA and LAGRANGE concepts significantly out-perform the geostationary concepts in all science metrics

Orbits

Concept	Arm variation (%)	Interior Angle variation (deg)	Range Rate (m/s)
GEOGRAWI/GADFLI	.02	.02	1
OMEGA	.1	12	160
LAGRANGE	.05	5 (20)	150 (360)
SGO-High	.01	0.8	13

- GEOGRAWI/GADFLI provide a much more stable constellation.
- Station keeping needed for LAGRANGE
- 6-SC design of OMEGA mitigates interior angle change
- Single-bench design of LAGRANGE exacerbates interior angle change

Mission Design

Concept	LV C3 $(km/s)^2$	PM Δv (m/s)	Cruise duration (months)
GEOGRAWI/GADFLI	-9.0	1	4
OMEGA	-1.6	500	13
LAGRANGE	-1.7	800	7-9
SGO-High	0.3	1100	14

- GEOGRAWI/GADFLI orbits are less costly to reach than OMEGA/LAGRANGE
- GEOGRAWI/GADFLI may be able to use micro-thrusters for orbit insertion
- GEOGRAWI/GADFLI also require de-orbit or boost into graveyard orbit after science operations. May still require PM

Sun Angle & Eclipses

Concept	In-plane Orbital Period (days)	Annual solar elevation change (deg)	Biannual Eclipse Season Duration (days)	Eclipses / Season
GEOGRAWI/ GADFLI	1	23.5	40	120
OMEGA	55	5	14	0.75
LAGRANGE	30	5	21	2

- Thermal fluctuation period compared with measurement band
- Loss of signal during eclipse & recovery time
- There will be an "exposure season" centered in the eclipse season when the Sun-link angle becomes small. This will require some mitigation strategy.

Technology Development

- **Gravitational Reference Sensor**
  - GADFLI baselines LPF GRS, highest TRL within group
  - GEOGRAWI & LAGRANGE baseline spherical proof mass, technology development effort needed to raise TRL
  - OMEGA baselines modified ONERA accelerometer. Concern that LPF GRS (37kg) may not fit in mass budget (80kg SC)
- **Sun filter**
  - ALL of these concepts require a strategy to mitigate Sun pointing events.
  - OMEGA specifies a filter that appears to meet optical performance. Concern with scaling to large size and maintaining pathlength stability.
  - Other strategies could be a shutter or re-pointing
- **Micro-Thrusters**
  - Station-keeping for LAGRANGE
  - Orbit insertion and decommissioning for GADFLI/GEOGRAWI
  - Low mass, power, volume for OMEGA

Risk Pro/Cons

- **OMEGA**
  - Con: Aggressive use of micro satellite architecture. May preclude heritage from LPF due to size/mass.
  - Pro: 6 SC arrangement provides redundancy
- **LAGRANGE:**
  - Con: Single proof mass per SC and redundancy

Recommendation

A majority of group members support recommending OMEGA as the Group 2 concept to undergo a Team-X study.

A dissenting minority recommended LAGRANGE