# Constraining dipolar radiation and modifications to dispersion relation with LISA

GdR: Fundamental Physics

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# Context

- GR is extremely well tested in solar system scale and observations of binary pulsars and GW are in excellent agreement with GR but important issues remain (Dark Matter, Dark Energy, Quantum Gravity...)
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  $\Rightarrow$ Theory agnostic analysis based on parametrized modifications to GR

# Project

- Goal: Place constraints on phenomenological modifications to GW generation and propagation
- Method: Multiband analysis in a bayesian framework

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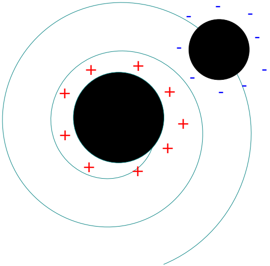

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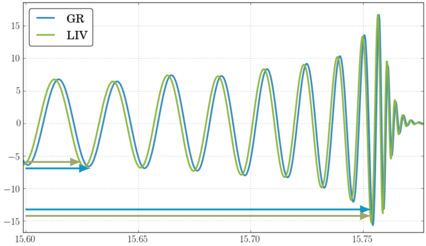


Figure: Comparison between waveforms with a superluminal graviton (green) and GR (blue). The waveforms have been aligned at the merger.

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- For dipolar radiation: $b = -1$ and $\beta \propto B$
- For dispersion relation: $b = \alpha - 1$ and $\beta \propto A_\alpha$

# Stellar Origin Black Holes

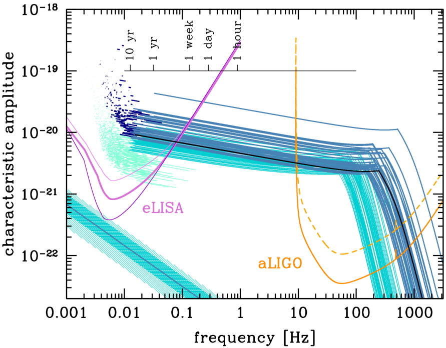


Figure: Multiband GW astronomy with Stellar Origin Black Holes (A. Sesana, PRL 2016)

- $\simeq 10^2$ expected to be detected in a 5 years LISA mission with $SNR > 8$ and merge in 10 years in LIGO/VIRGO band (A. Sesana, PRL 2016)

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- Simulate data in boths bands using PhenomD for the waveform

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- Compute evidences and bayes ratios: $\mathcal{B} = \frac{p(d|GR)}{p(d|MG)}$ to perform model selection

Run bayesian analysis only with GR parameters on GR signal in LISA

| Variable | True value | Recovered value with 90% confidence level interval |
|---|---|---|
| $m_1$ ($M_\odot$) | 50.63 | $54.39^{+19.6}_{-9.9}$ |
| $m_2$ ($M_\odot$) | 24.84 | $23.11^{+4.5}_{-5.1}$ |
| $a_1$ | 0.054 | $-0.048^{+0.54}_{-0.31}$ |
| $a_2$ | 0.0239 | $-0.0056^{+0.85}_{-0.86}$ |
| $D_L$ (Mpc) | 259 | $230^{+49}_{-55}$ |
| Sky position | $(10^\circ, 201^\circ)$ | $(10^\circ, 201^\circ)$, $\Omega = 0.4\ \mathrm{deg}^2$ |

# Constraints on dipolar emission

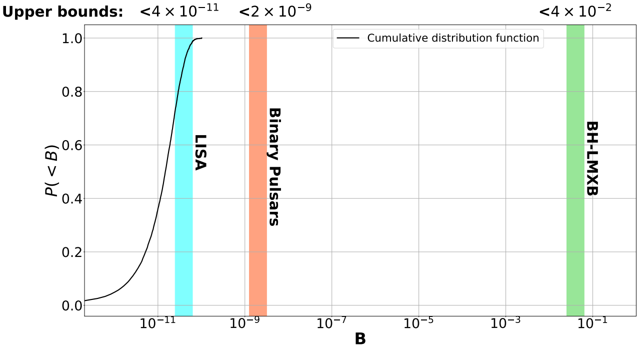


Figure: Allowed region for dipolar amplitude obtained with different measures (90% confidence level)

# Constraints on modifications with LISA

Run bayesian analysis considering the possibility of having phenomenological modifications on GR signal in LISA

| | $B$ | $m_g$ |
|---|---|---|
| Actual Constrains | BH-LMXB: $< 4 \times 10^{-2}$ Binary pulsars: $< 2 \times 10^{-9}$ | LIGO/VIRGO: $< 8 \times 10^{-23}$ Solar System: $< 7 \times 10^{-23}$ |

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| Dipolar Emission and Massive Graviton | $< 3 \times 10^{-10}$ | $< 1 \times 10^{-24}$ |
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**Work in progress**

Generate signal in LISA with dipolar emisison: $B = 1 \times 10^{-6}$

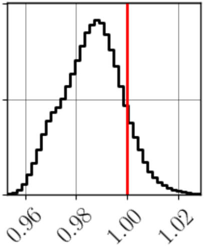


Figure: $10^6 B = 0.99 \pm 0.019$

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- Makes the detection of modifications harder
- Analysis based on Fisher matrix might not be reliable

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Next:

- Combining observations from LISA and $3^{rd}$ generation of ground based detectors should improve parameter estimation and constraints on modifications to GR
- Compute evidences for different systems