Supermassive Black Hole Binaries as LISA sources

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Outline

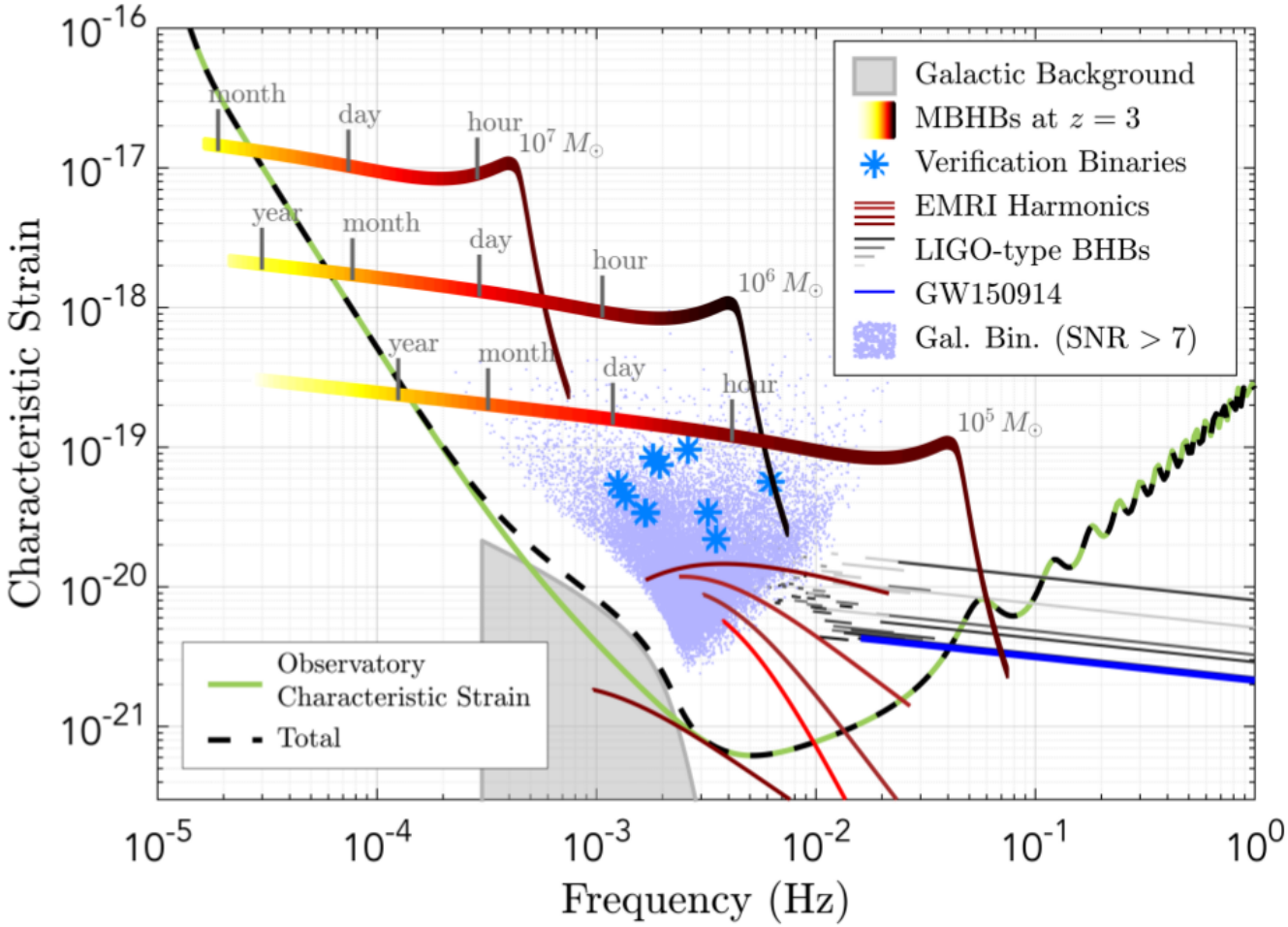
SMBHBs with LISA

Supermassive black hole binaries are one of the main science targets for LISA.

Long-lived signals with high SNRs will allow for precise measurements of various aspects of GW signals, such as spin-induced precession, multiple ringdown modes measurements, etc.

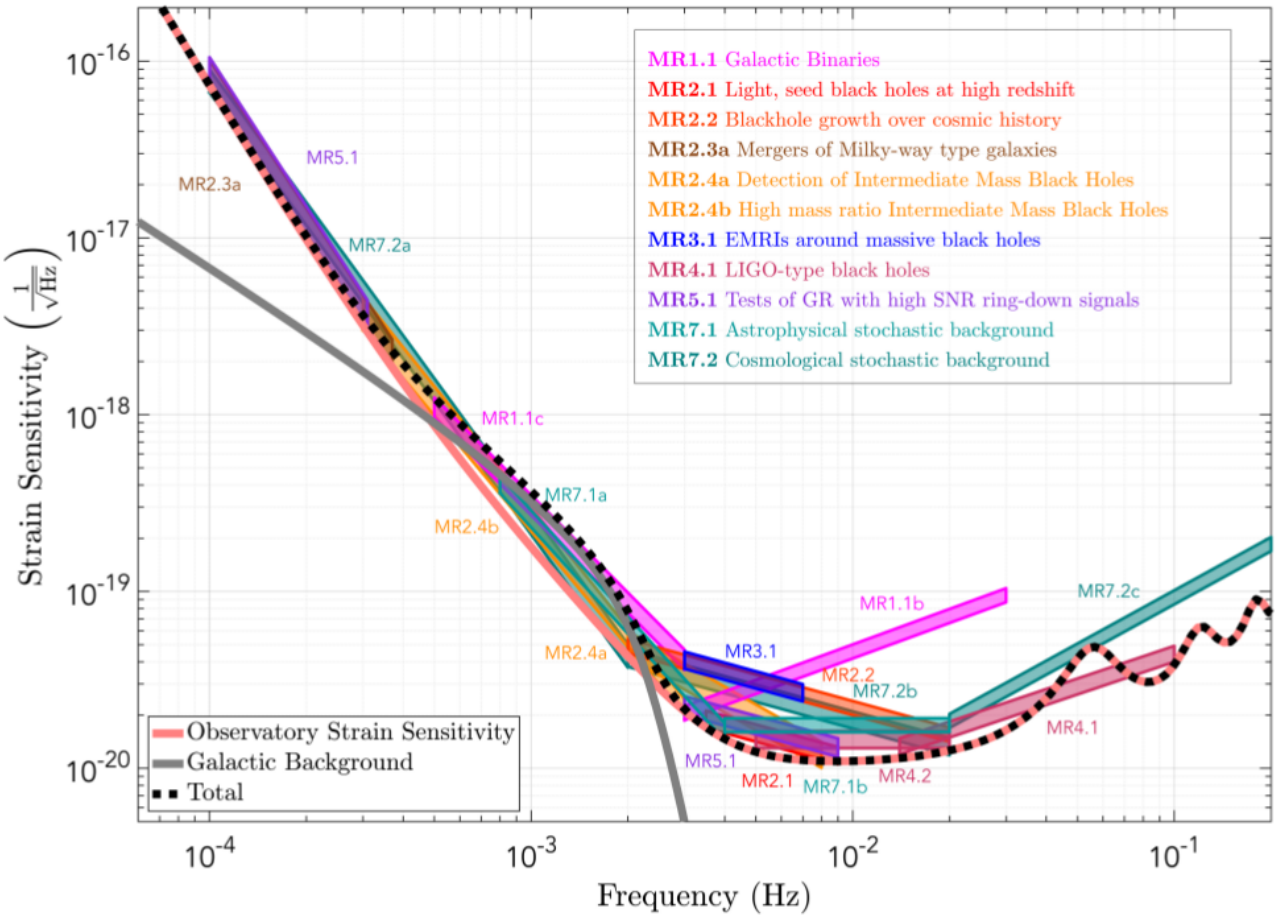
The high horizon distance in a broad mass range will allow for supermassive black hole evolution model selection.

SMBHB signals



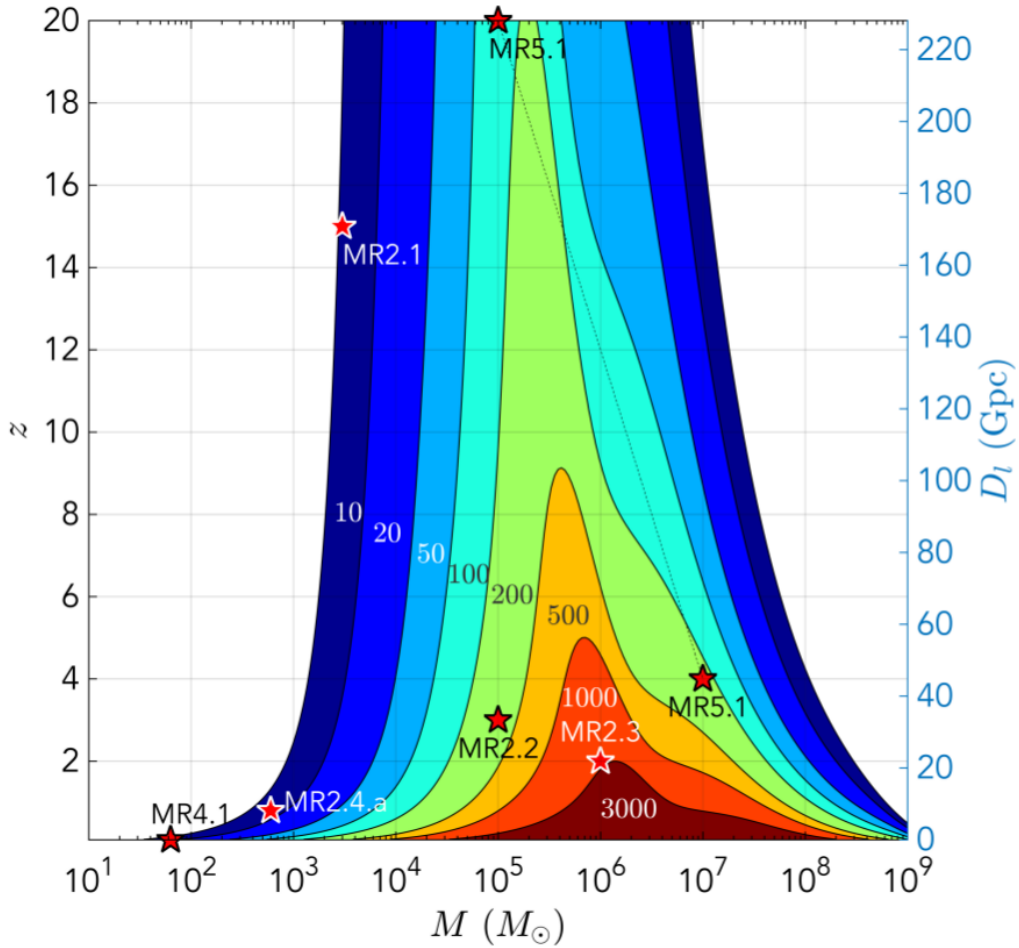
[Amaro-Seoane+ (arXiv: 1702.00786)]

Science targets



[Amaro-Seoane+ (arXiv: 1702.00786)]

Horizon distance



[Amaro-Seoane+ (arXiv: 1702.00786)]

Astrophysical study

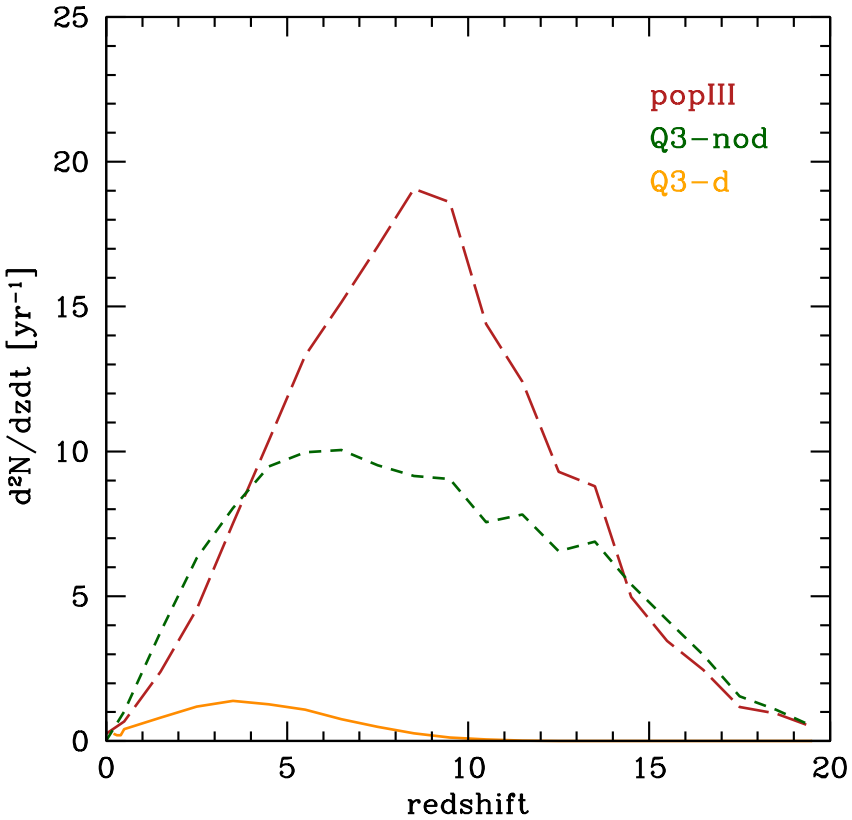
Two different black hole seeds scenarios:

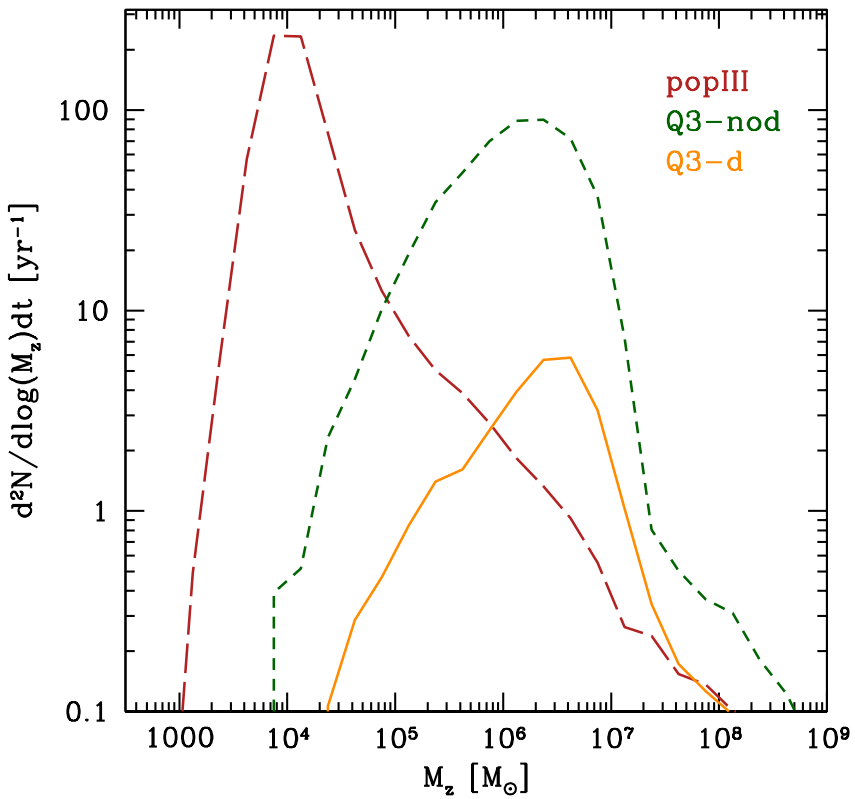
Light seeds: popIII remnants, black holes form with initial masses around $200 M_{\odot}$ between redshifts 15 and 20.

Heavy seeds: black holes are present with masses around $10^5 M_{\odot}$ between redshifts 15 and 20. We considered two models with critical Toomre parameter $Q_c = 2$ and $Q_c = 3$.

Delay between galaxy merger and black hole merger can be important, as black holes can be driven to the center of the merged galaxy on timescales of a few Gyrs.

Models


popIII
Q3−nod
Q3−d
d²N/dzdt [yr⁻¹]
redshift
0
5
10
15
20
25


popIII
Q3−nod
Q3−d
d²N/dlog(M_z)dt [yr⁻¹]
M_z [M_⊙]
0.1
1
10
100
1000
10⁴
10⁵
10⁶
10⁷
10⁸
10⁹

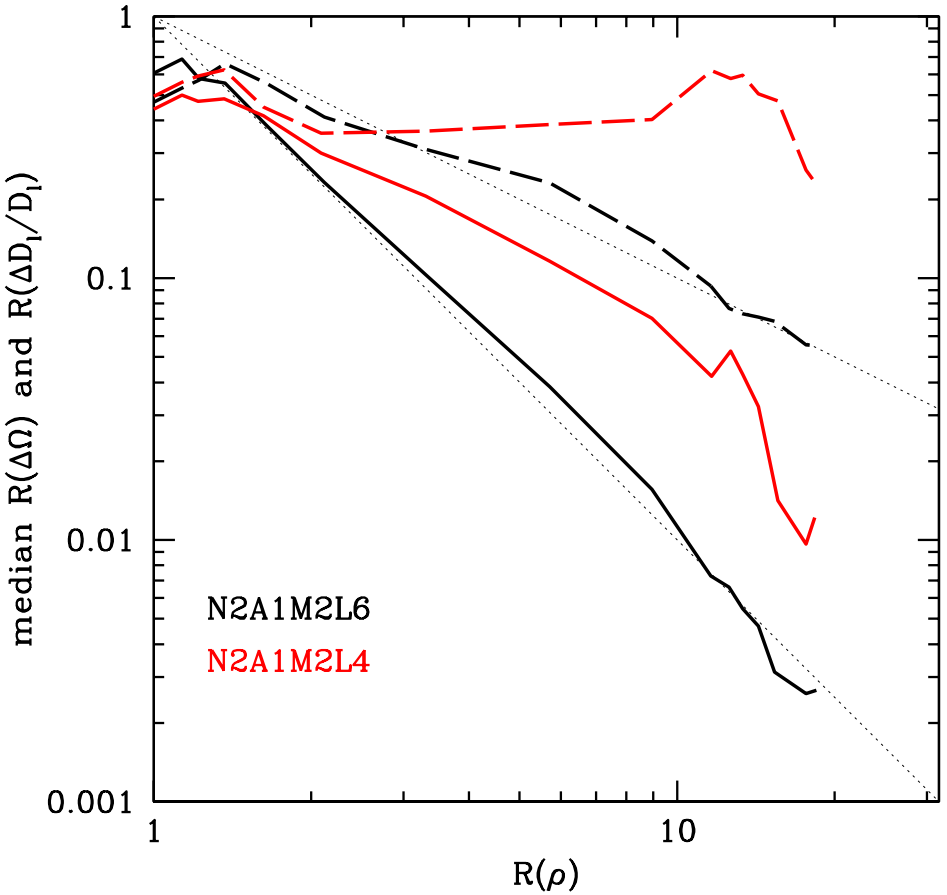
Parameter Estimation

We used Fisher matrix analysis to compute measurement errors on the parameters, using spin-precessing inspiral-only waveforms with higher harmonics.

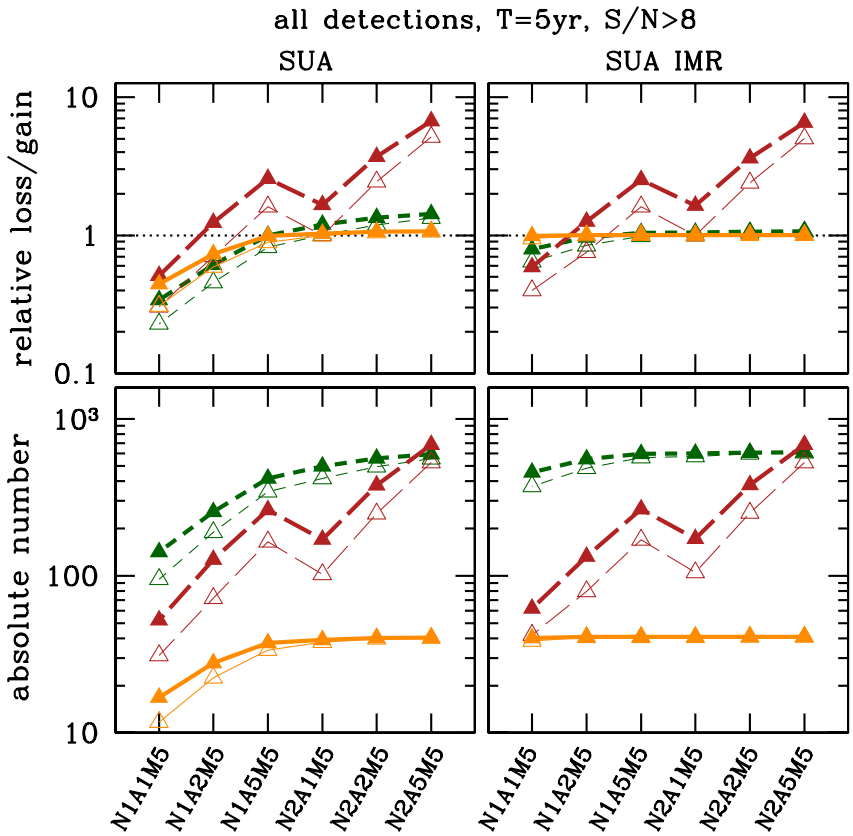
We computed the SNR ratio between IMR and inspiral-only to rescale the SNR using the phenomC waveforms.

We rescaled the measurement errors on extrinsic parameters using results from a few spin-precessing IMR hybrid waveforms.

Measurement Error Gain

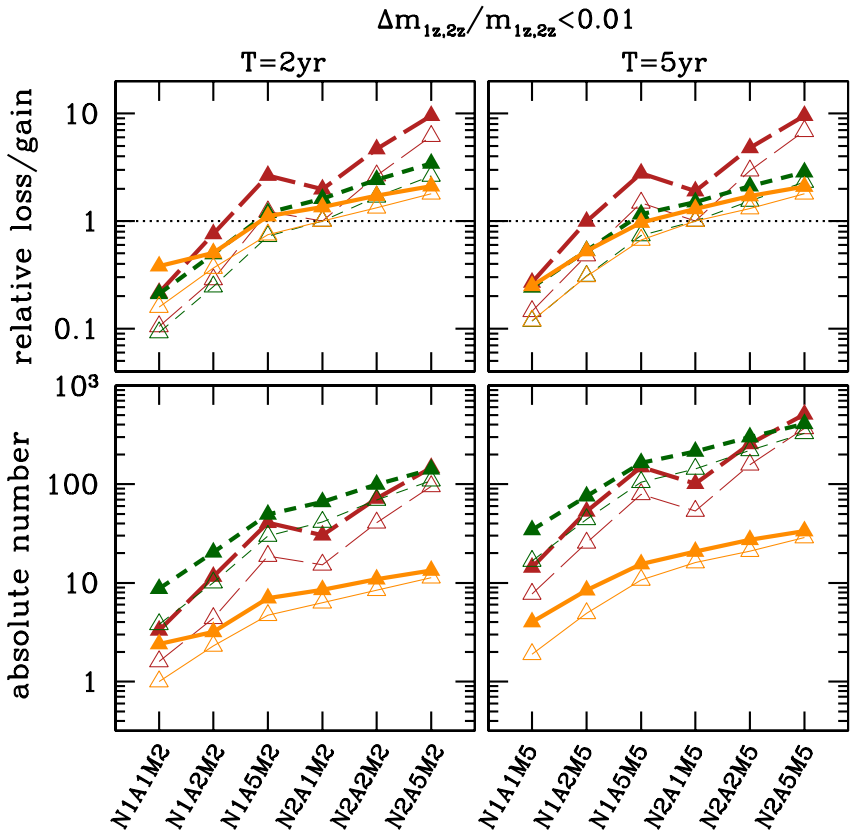


Detections from astrophysical populations



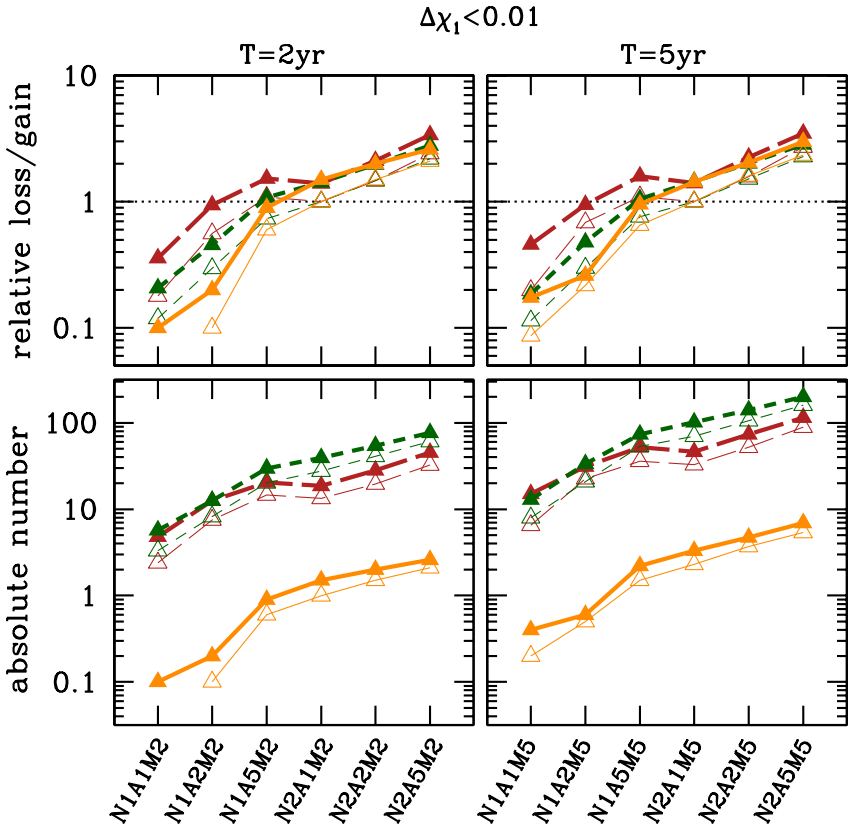
[AK+ (arXiv: 1511.05581)]

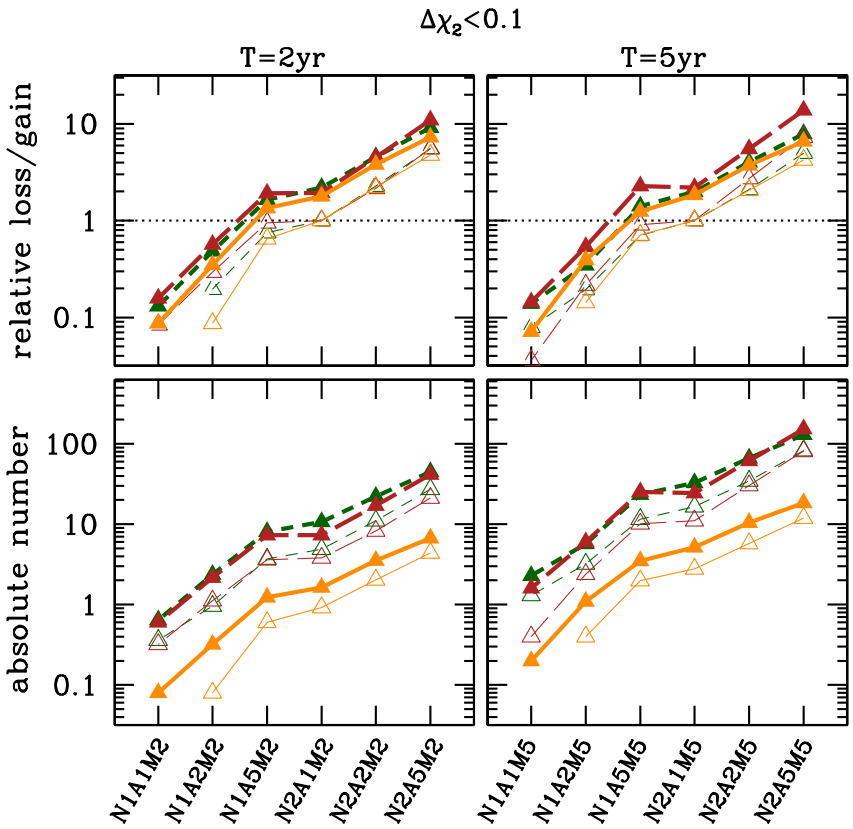
Mass measurement



[AK+ (arXiv: 1511.05581)]

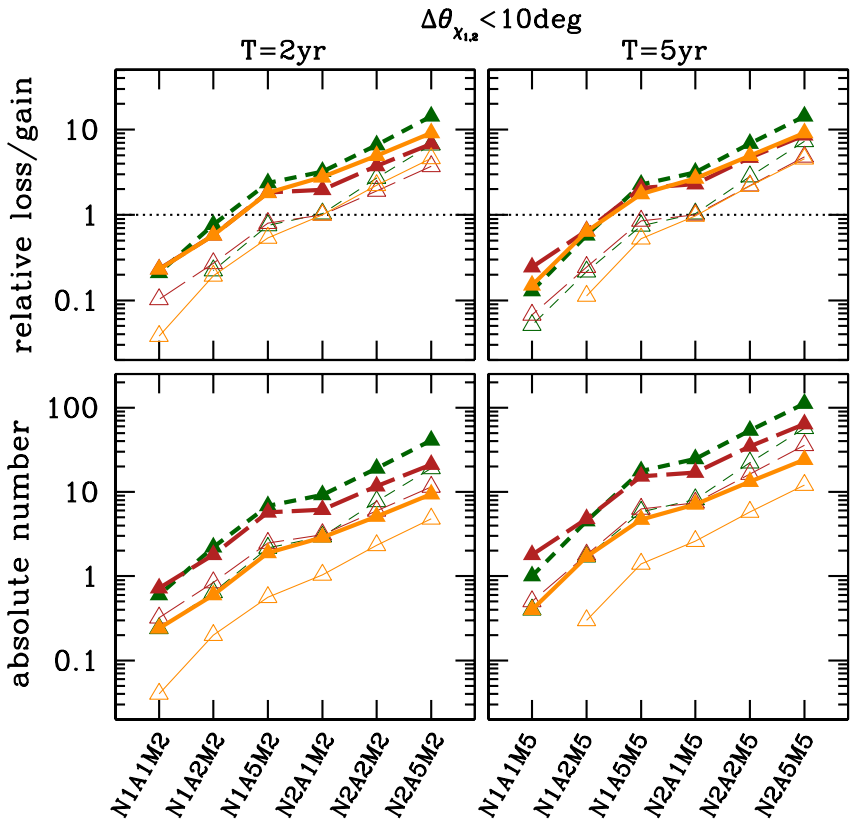
Spin measurement





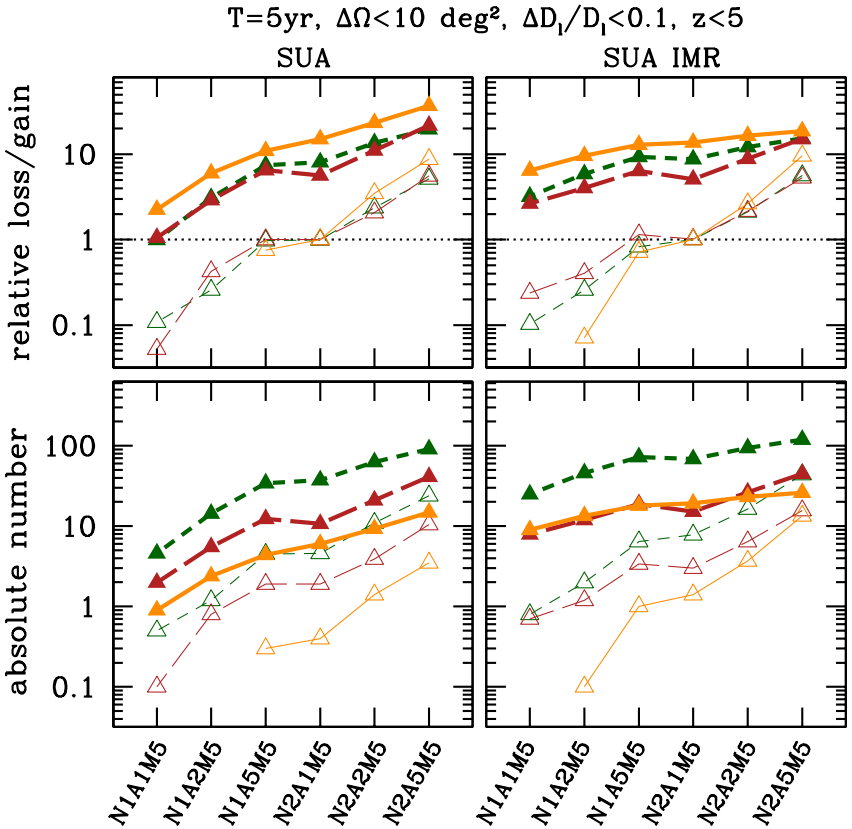
[AK+ (arXiv: 1511.05581)]

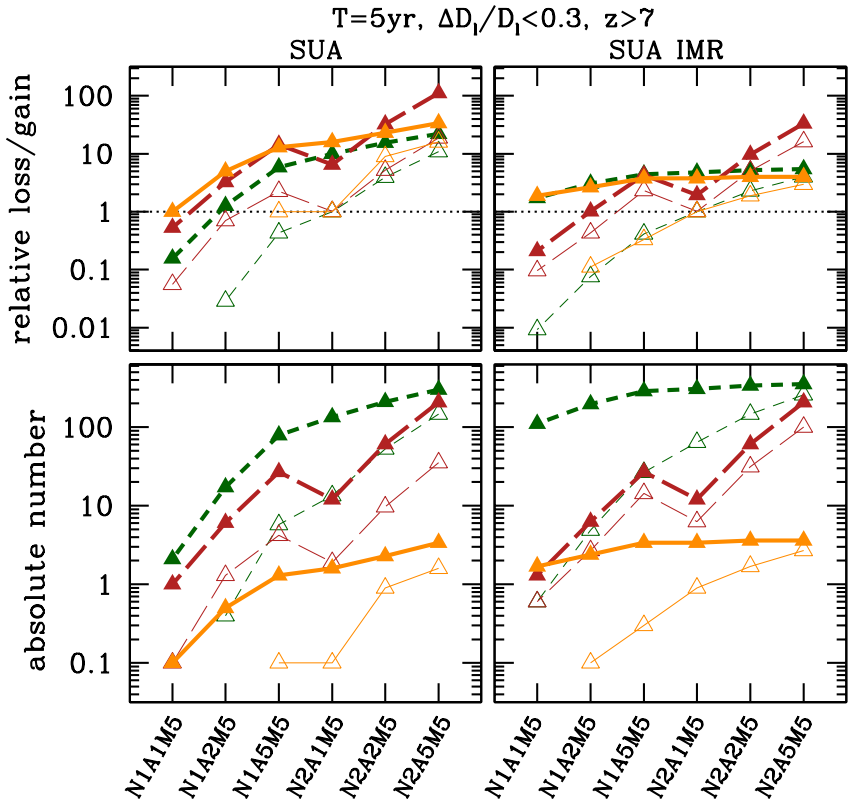
Spin alignment angle



[AK+ (arXiv: 1511.05581)]

Astronomy





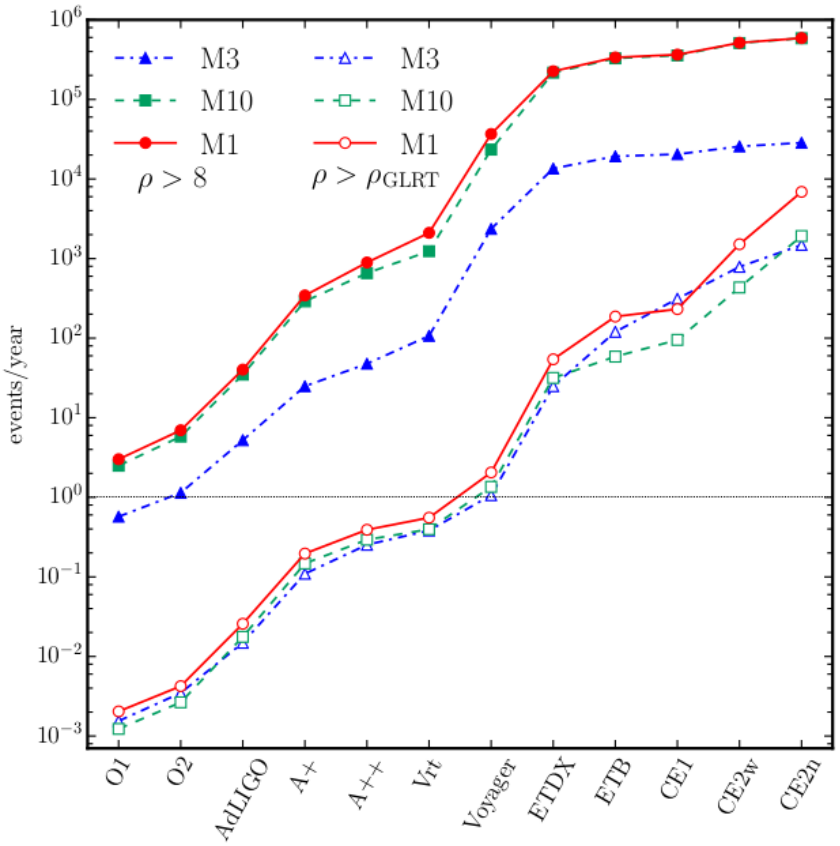
[AK+ (arXiv: 1511.05581)]

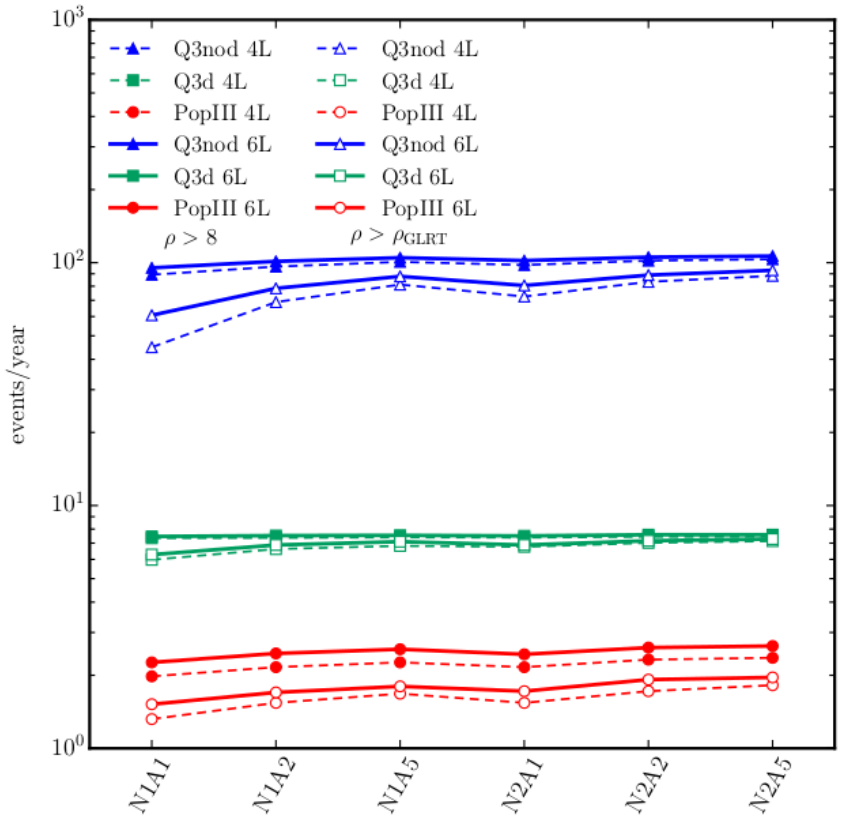
Ringdown measurement

High SNRs will allow the simultaneous detection of multiple ringdown modes, allowing Kerrness tests for the remnant objects.

The bucket of the LISA noise curve corresponds to the ringdown frequencies of Sagittarius A*-type black holes.

Ringdown measurement





[Berti+ (arXiv:1605.09286)]

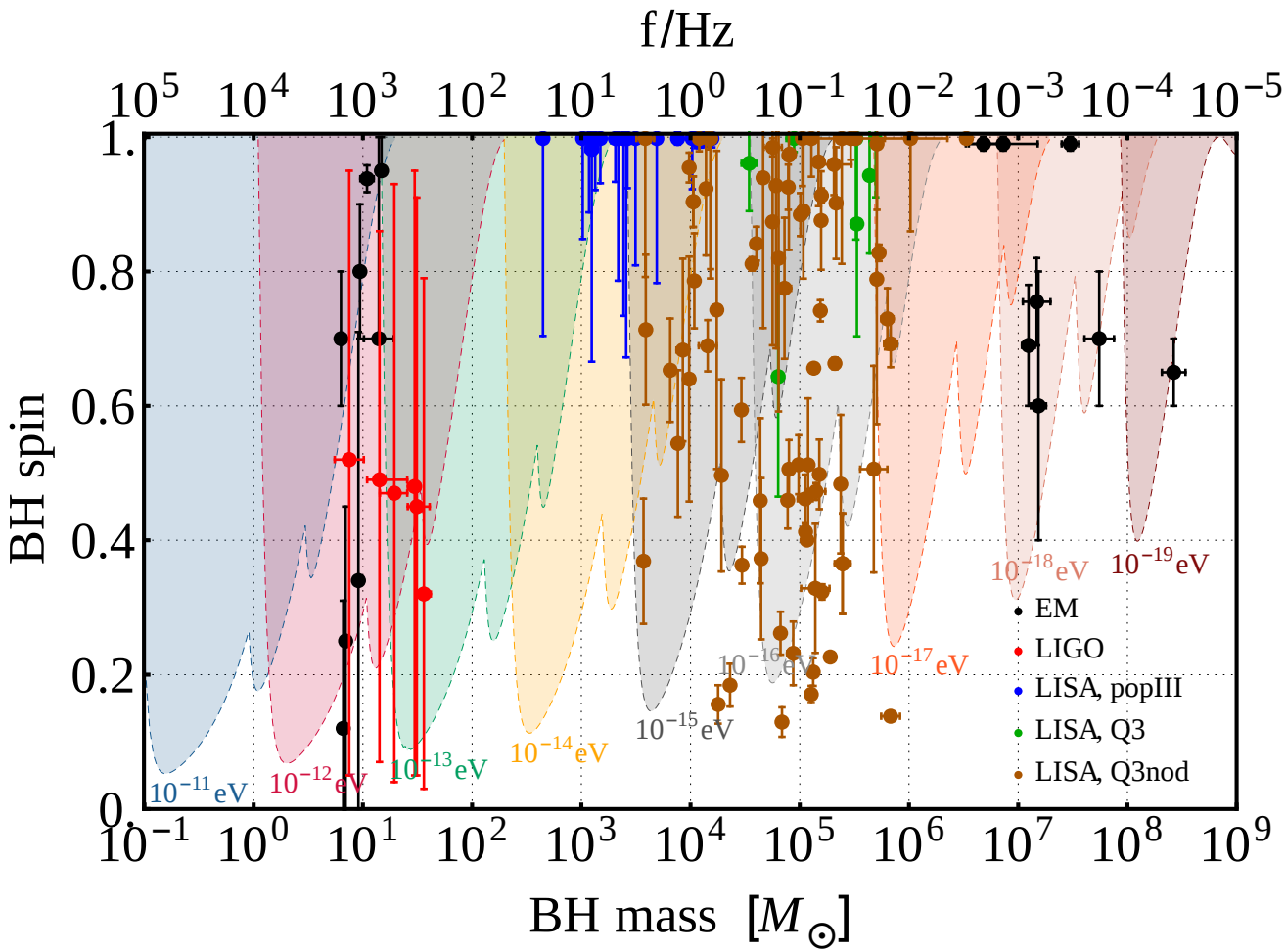
Axion-like particles

The presence of ultralight bosons ($m \sim 10^{-17}$ eV - 10^{-13} eV) will trigger superradiant instabilities that will drain angular momentum from BHs.

By measuring the spins and masses of binary components, we can detect holes in the mass-spin plane that would be a signature of the presence of such bosons.

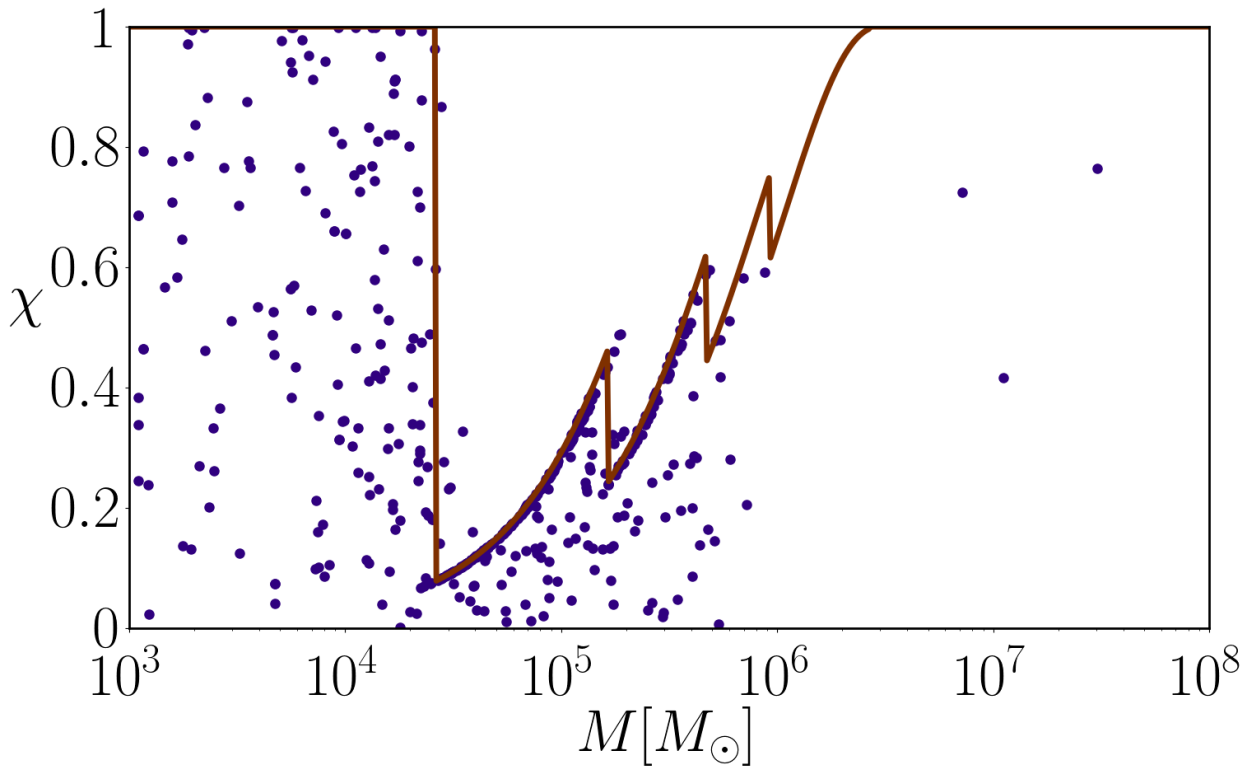
LISA will allow us to either reject ultralight bosons in a certain mass range, or if present to detect them and measure their mass with $\sim 10\%$ accuracy.

Black hole populations



[Brito+ (arXiv:1706.06311, 1706.05097)]

Black hole populations



[Brito+ (arXiv:1706.06311, 1706.05097)]

Conclusion

Tens to several hundreds of SMBH mergers are expected, and will help constrain SMBH evolution models, with good mass, spin, and spin alignment measurements.

SMBH mergers will allow important theoretical tests as well through different means.