# Supermassive Black Hole Observations with eLISA


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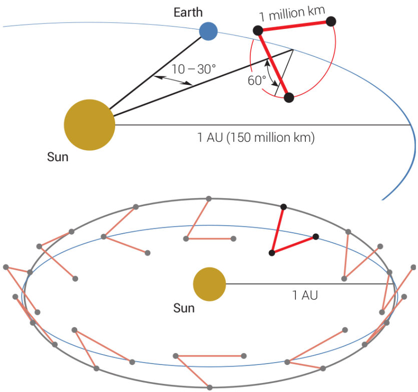
# Outline

# Orbits sketch



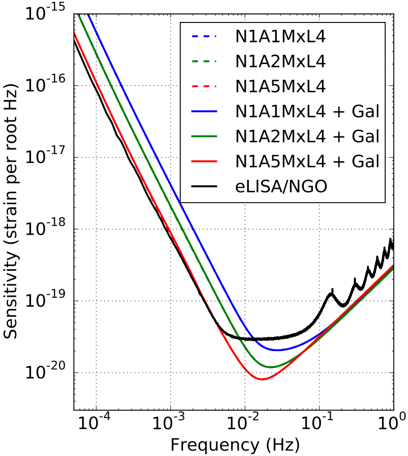

[Image: P. Amaro-Seoane et al., The Gravitational Universe, arXiv:1305.5720]

# Variable parameters

The goals of the study is to compare the science impact of different eLISA design choices.

- Different armlengths: 1Gm, 2Gm, 5Gm.
- Different acceleration noise performance: N2 (Pathfinder design), N1 (10 times worse).
- Different mission durations: 2 years, 5 years.
- Four or six laser links between the satellites.

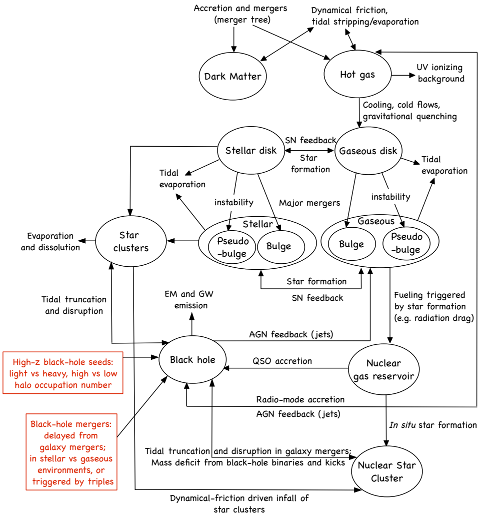
# Noise curves



# Study

- Simulated 10 realizations of a 5 year merger catalog for 6 different galaxy evolution models.
- Selected 3 representative models.
- Simulated parameter estimation for each system using 24 different mission designs.

# Contents



Accretion and mergers (merger tree)
Dynamical friction, tidal stripping/evaporation
Dark Matter
Hot gas
UV ionizing background
Cooling, cold flows, gravitational quenching
Stellar disk
SN feedback
Star formation
Gaseous disk
Tidal evaporation
Tidal evaporation
instability
Major mergers
instability
Stellar
Pseudo -bulge
Bulge
Gaseous
Bulge
Pseudo -bulge
Evaporation and dissolution
Star clusters
Star formation
SN feedback
Tidal truncation and disruption
EM and GW emission
Fueling triggered by star formation (e.g. radiation drag)
AGN feedback (jets)
High-z black-hole seeds: light vs heavy, high vs low halo occupation number
Black hole
QSO accretion
Nuclear gas reservoir
Radio-mode accretion
AGN feedback (jets)
*In situ* star formation
Black-hole mergers: delayed from galaxy mergers; in stellar vs gaseous environments, or triggered by triples
Tidal truncation and disruption in galaxy mergers;
Mass deficit from black-hole binaries and kicks
Nuclear Star Cluster
Dynamical-friction driven infall of star clusters

# Contents

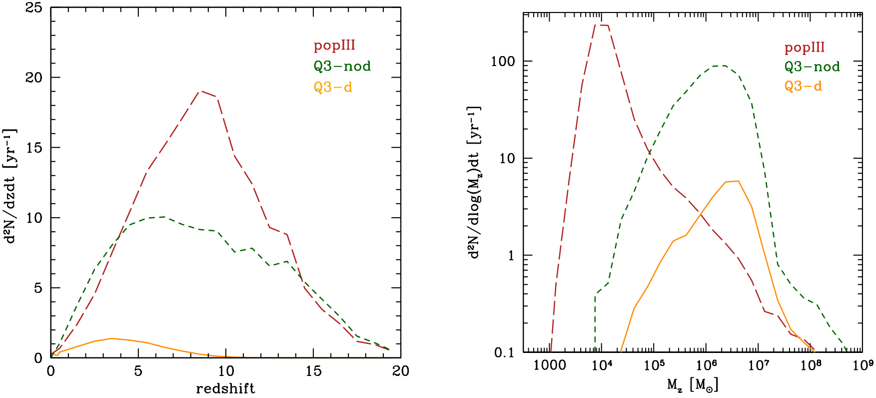
Two different black hole seeds scenarios:

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
d²N/dlog(Mz)dt [yr⁻¹]
Mz [M⊙]
0.1
1
10
100
1000
10⁴
10⁵
10⁶
10⁷
10⁸
10⁹

# Waveforms

We used three different waveform models:

- A precessing, inspiral-only waveform with higher harmonics (SUA)
- A nonprecessing, IMR restricted waveform (phenomC)
- A set of precessing IMR hybrid waveforms

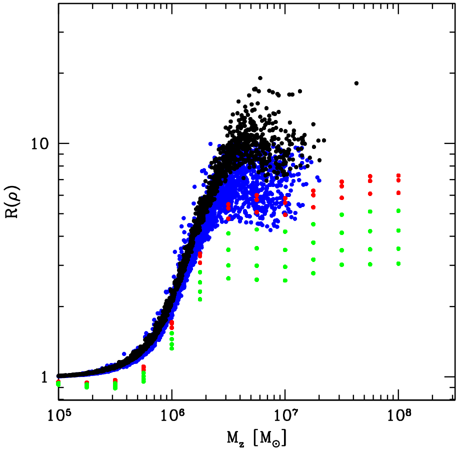
# Parameter Estimation

We use Fisher matrix analysis to compute measurement errors on the parameters, using the SUA waveforms.

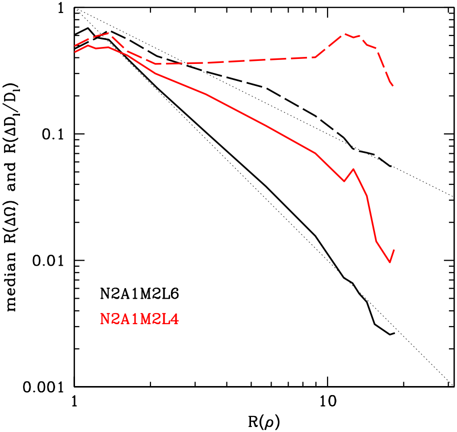
We compute the SNR ratio between IMR and inspiral only to rescale the SUA SNR using the phenomC waveforms.

We rescale the measurement errors on extrinsic parameters using results from the phenomC and hybrid waveforms.

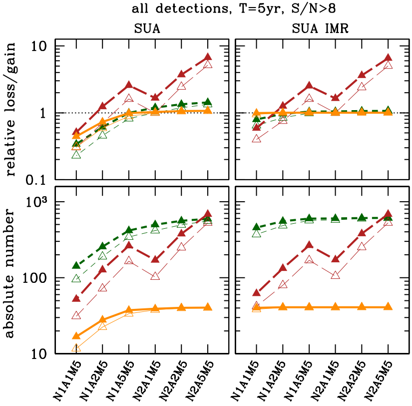
# SNR Gain

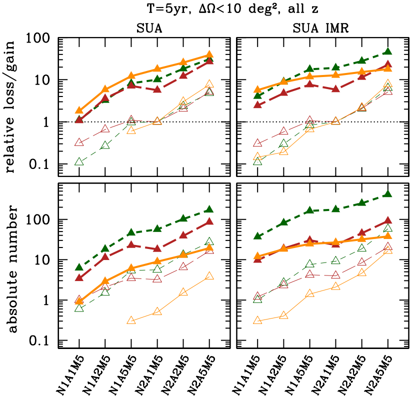


# Measurement Error Gain

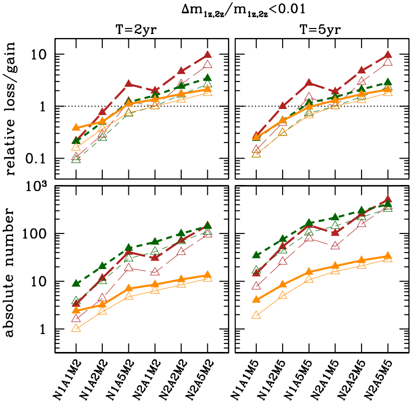


# Total Detections

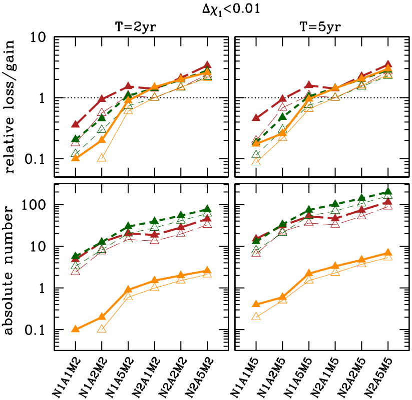


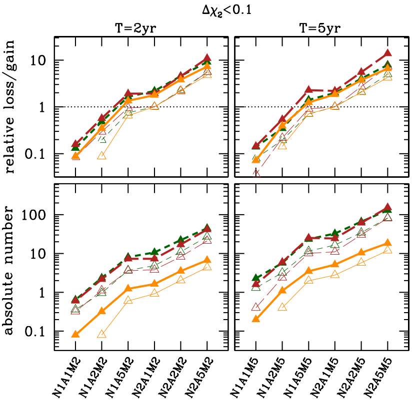



# Mass determination

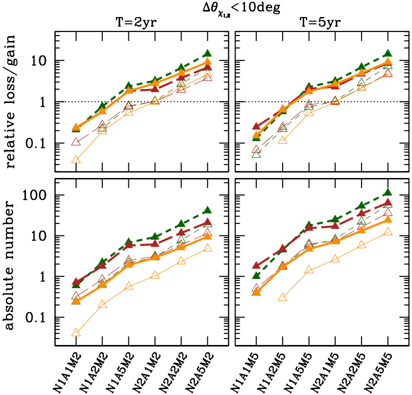


# Spin determination

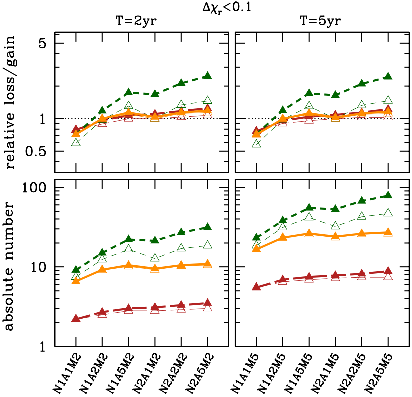


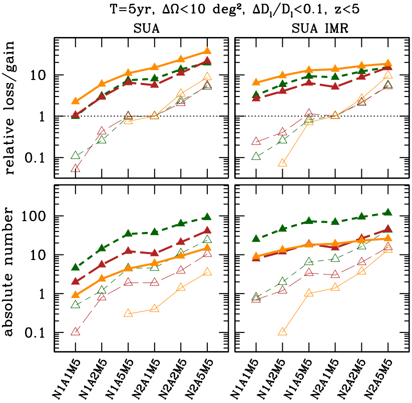
# Spin alignment angle

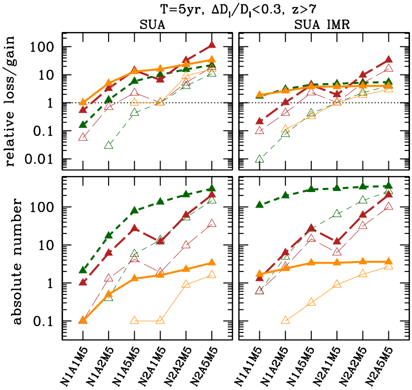


# Remnant spin

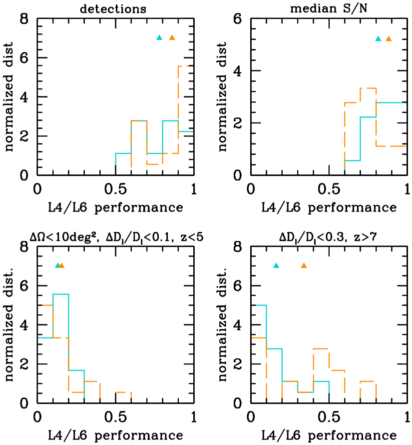


# Astronomy

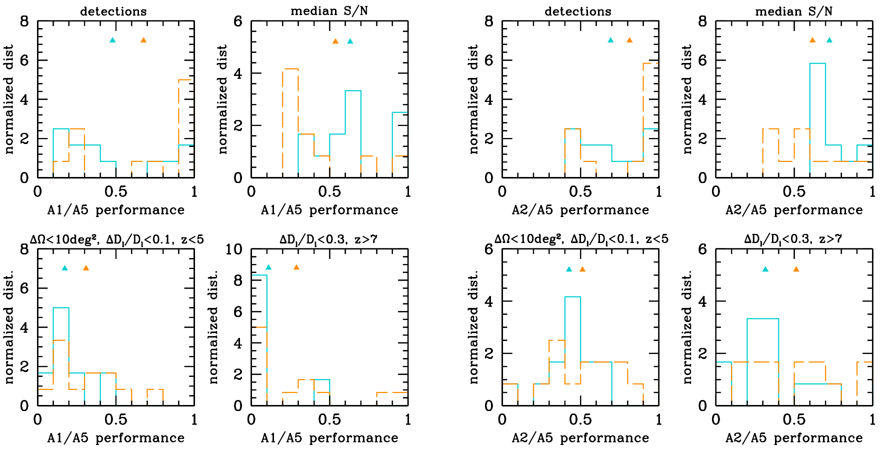

T=5yr, ΔΩ<10 deg², ΔD_l/D_l<0.1, z<5
SUA
SUA IMR
relative loss/gain
absolute number
0.1
1
10
100
N1A1M5
N1A2M5
N1A5M5
N2A1M5
N2A2M5
N2A5M5


T=5yr, ΔD_l/D_l<0.3, z>7
SUA
SUA IMR
relative loss/gain
absolute number
0.01
0.1
1
10
100
N1A1M5
N1A2M5
N1A5M5
N2A1M5
N2A2M5
N2A5M5

# Number of Links



# Armlength


detections
median S/N
detections
median S/N
normalized dist
A1/A5 performance
A2/A5 performance
ΔΩ<10deg², ΔD_l/D_l<0.1, z<5
ΔD_l/D_l<0.3, z>7
normalized dist.

# Conclusion

- All designs offer good number of detections and mass determination.
- Good low-frequency noise allows probing feeding mechanism through spin measurements.
- All designs offer good remnant spin measurement.
- To identify electromagnetic counterparts, having six links is important.
- To identify high redshift systems, having six links is also important.
- Overall, reducing the armlength to 2Gm is the least harmful way to reduce cost with respect to classic LISA.