

Synergies: tests of gravity and formation of supermassive black holes

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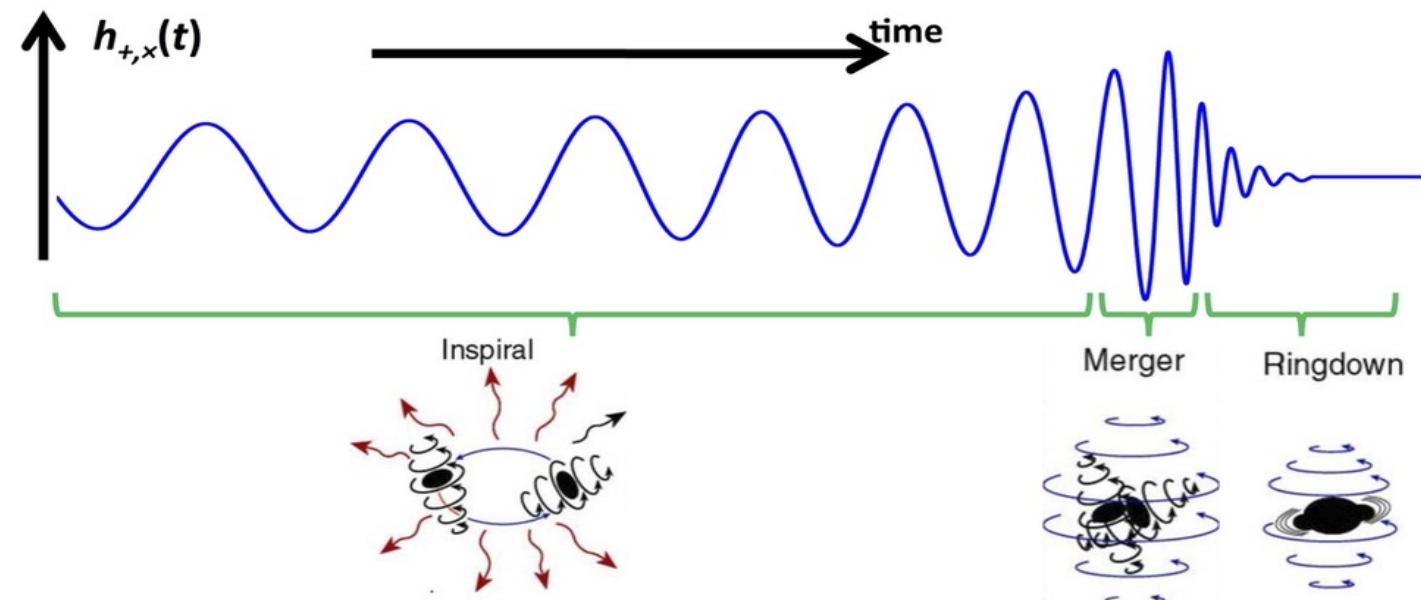
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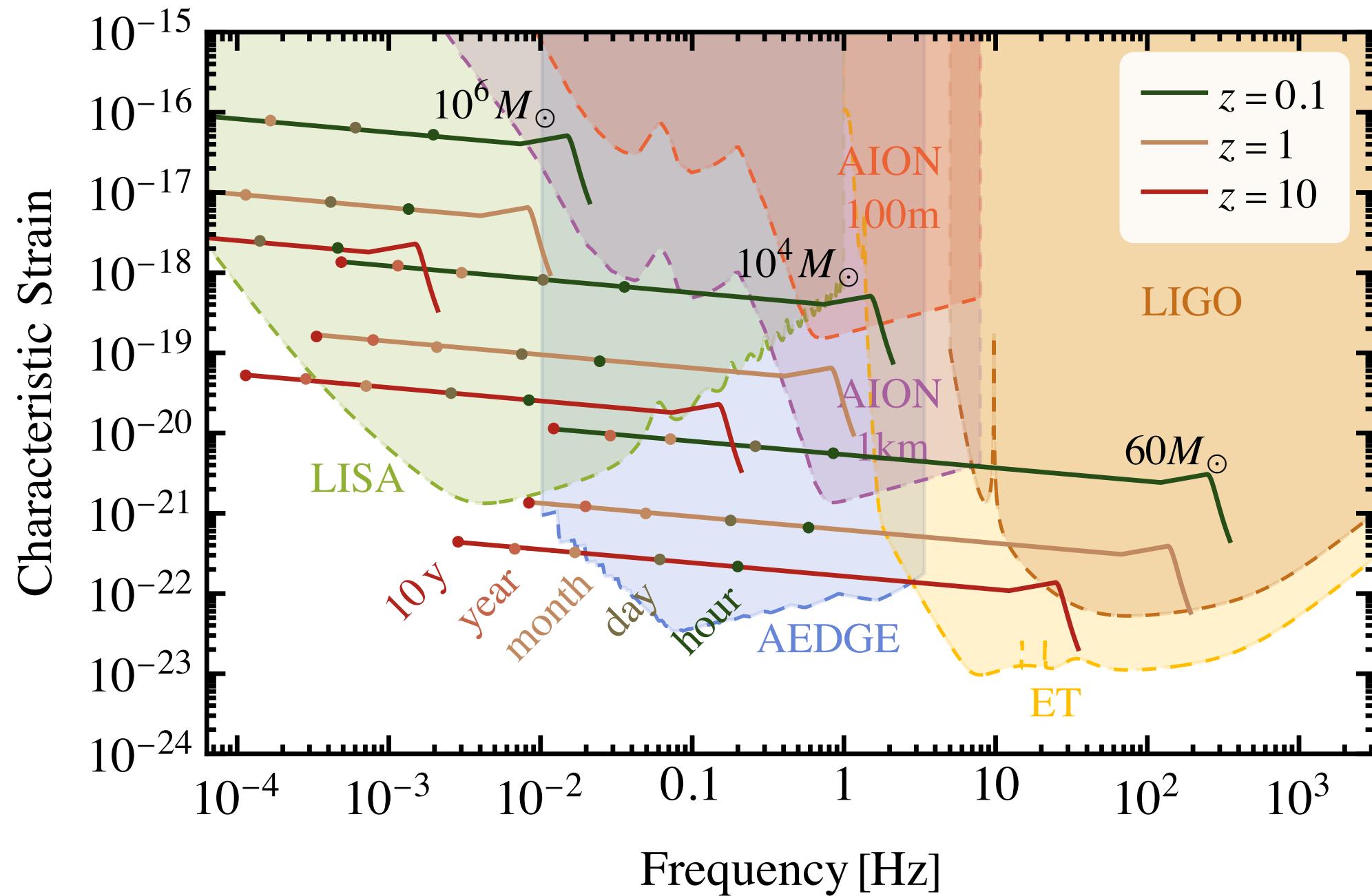
AI workshop, CERN, March 14, 2023.

Outline

1. Stellar mass binary inspirals

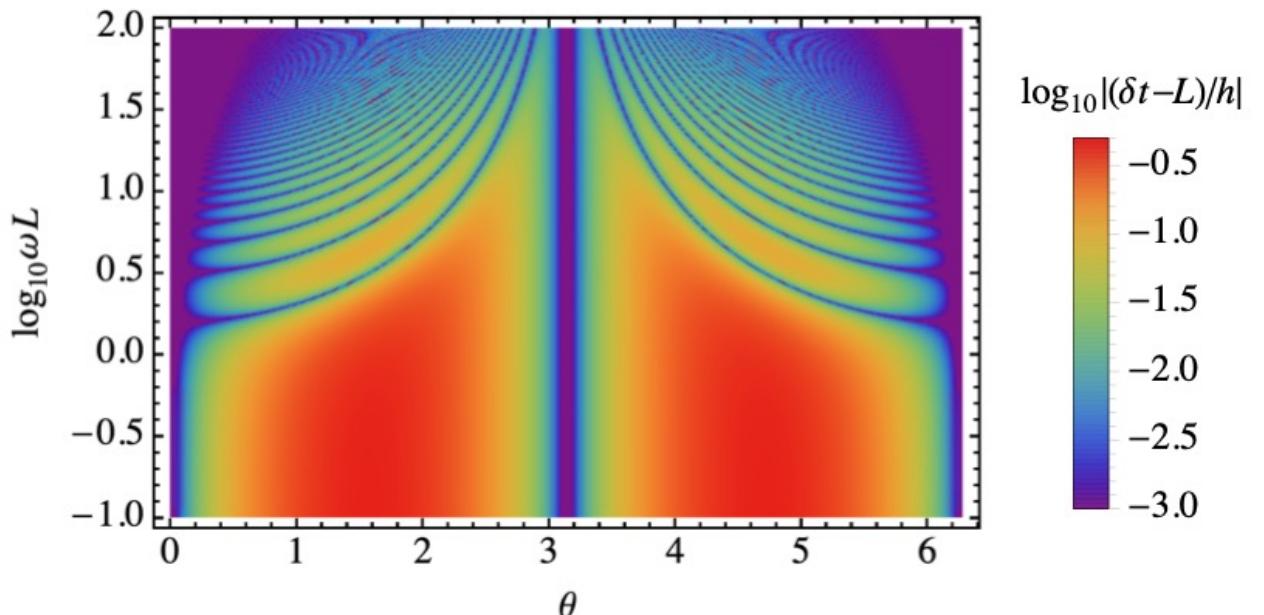
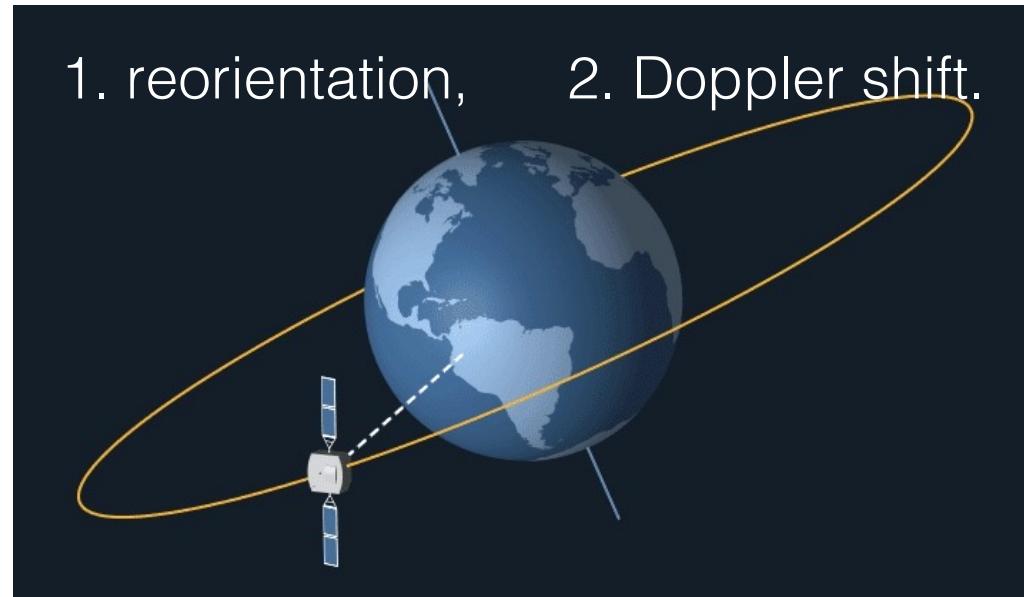
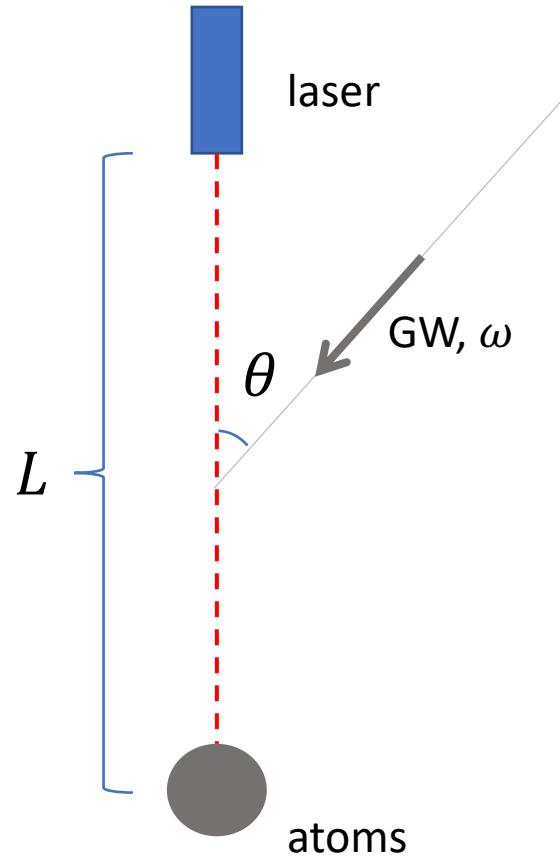
2. Intermediate mass black hole (IMBH) mergers





1. Stellar mass binary inspirals

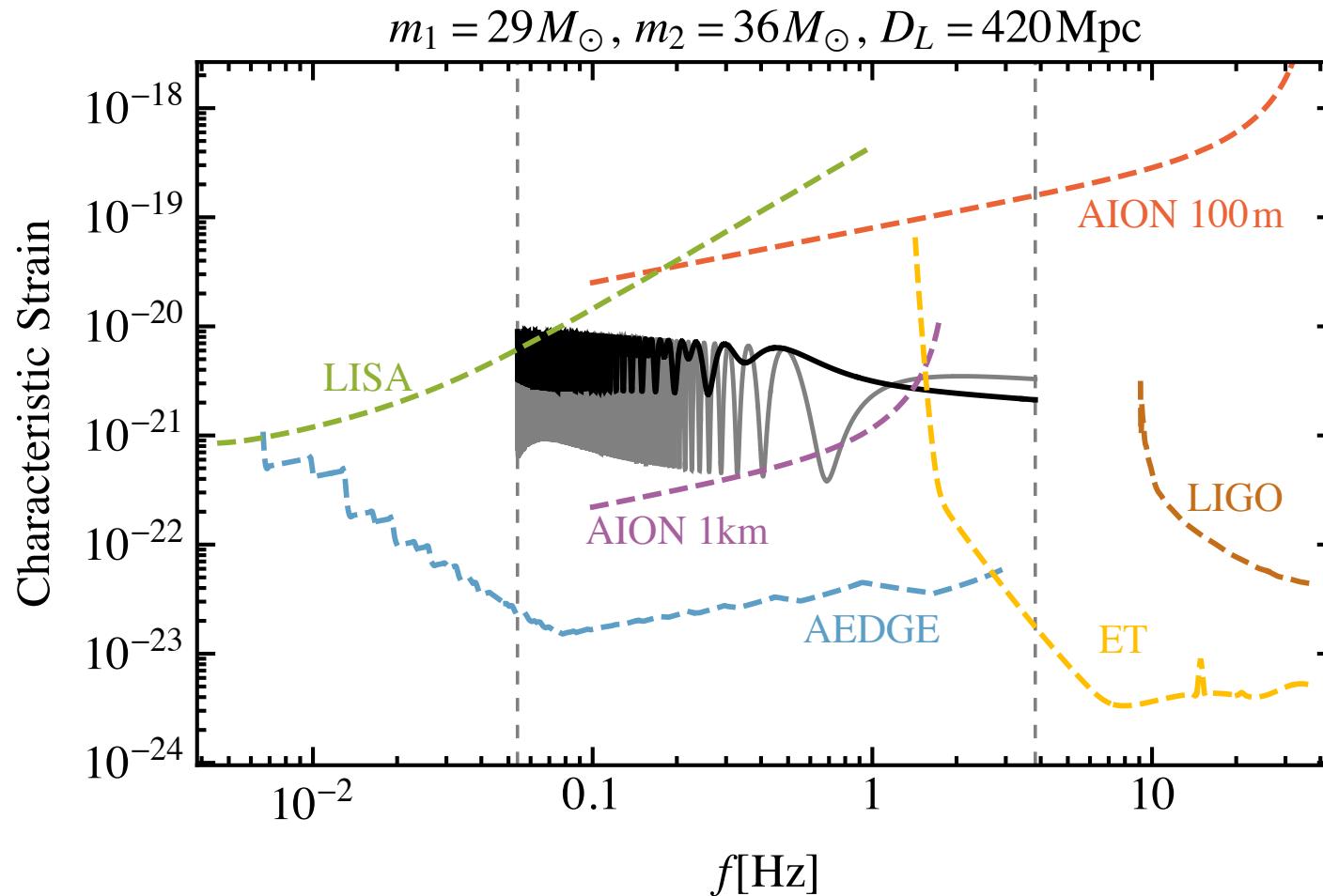
Effect of GWs



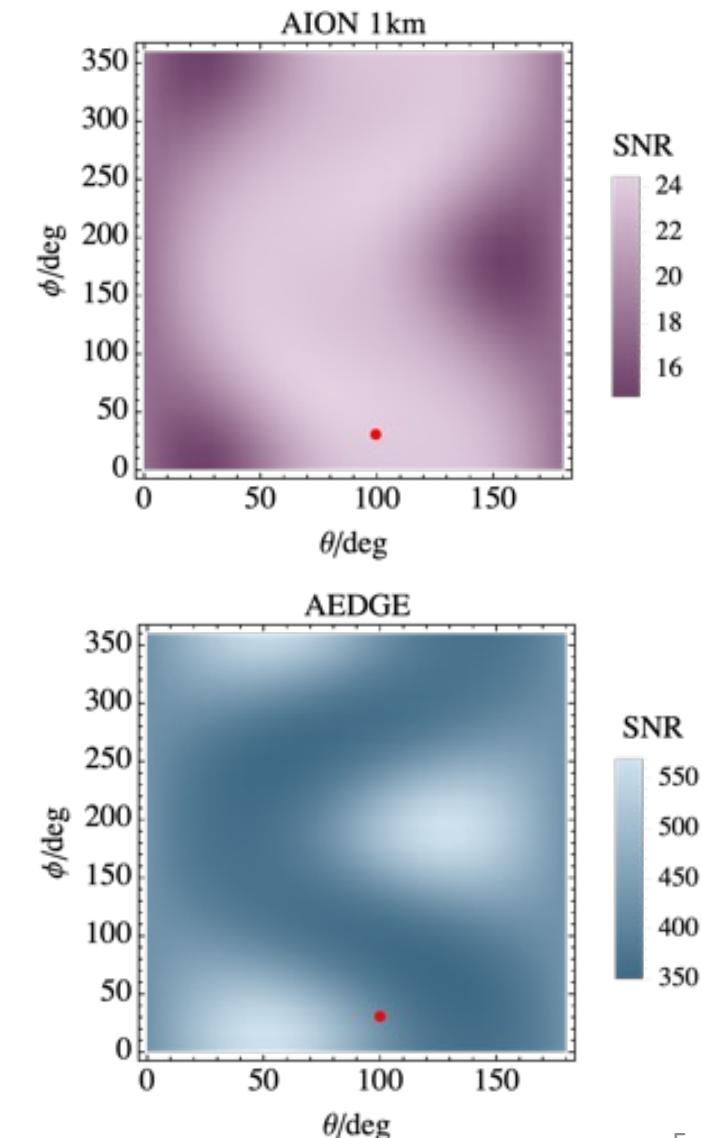
Observing binary inspirals

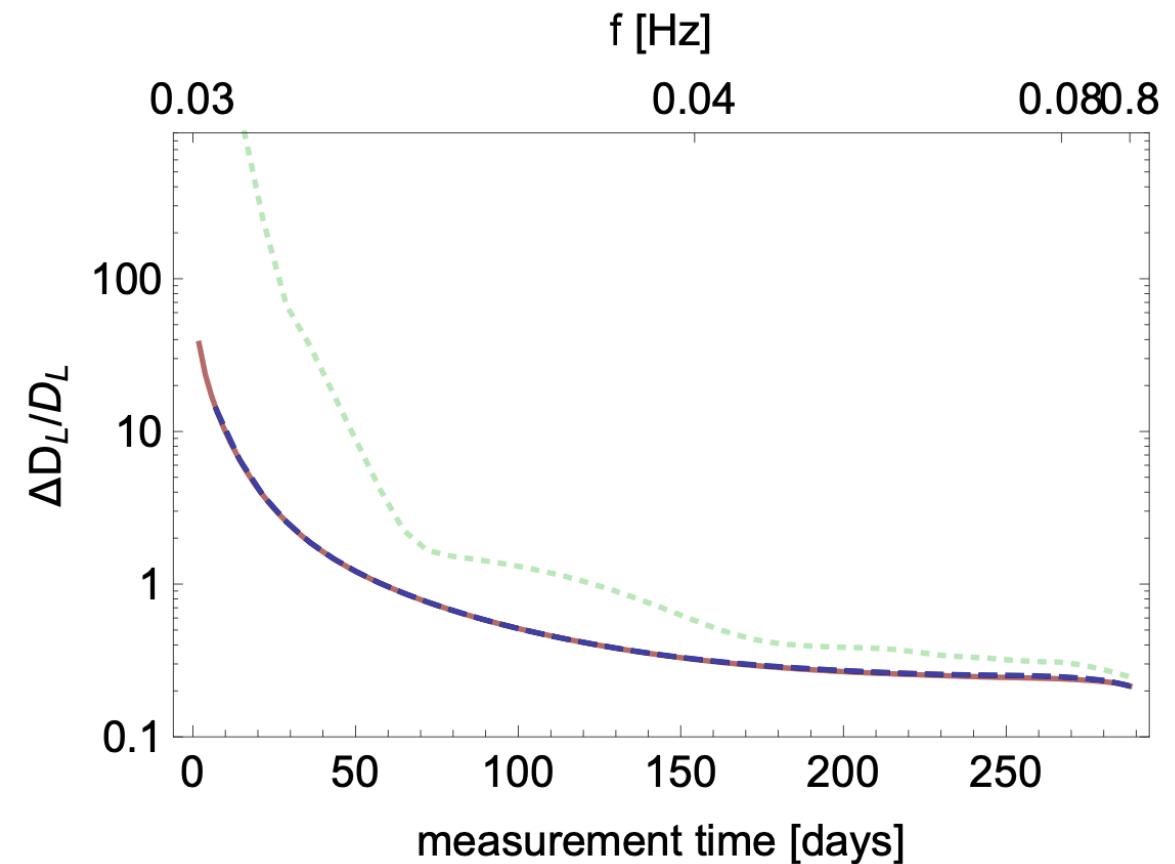
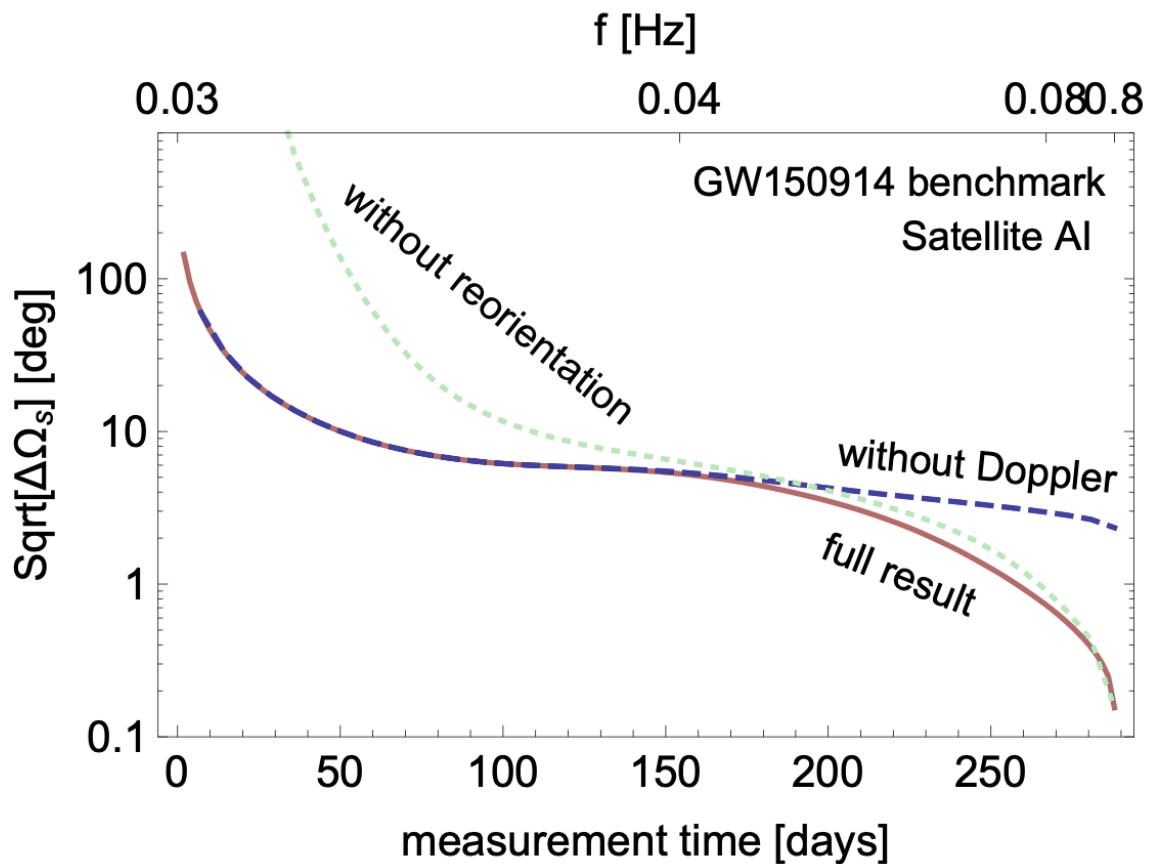
J. Ellis and V. Vaskonen, 2003.13480

GW150914-like source:



LIGO: SNR = 24

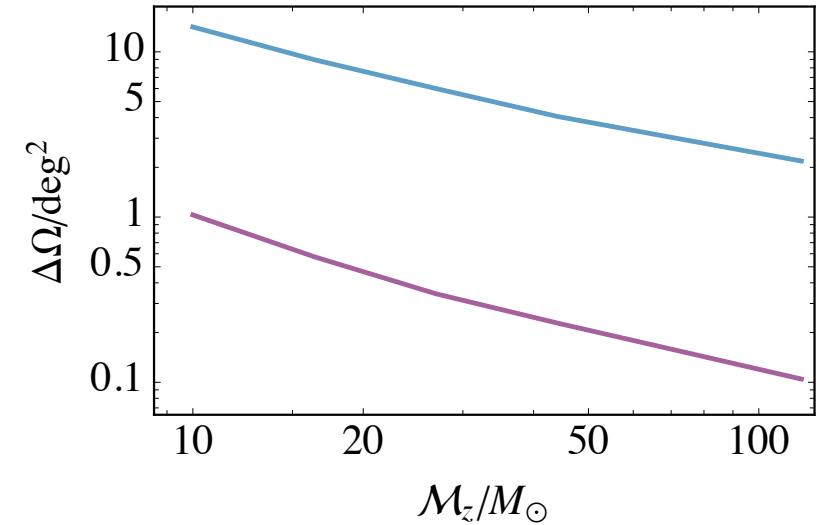
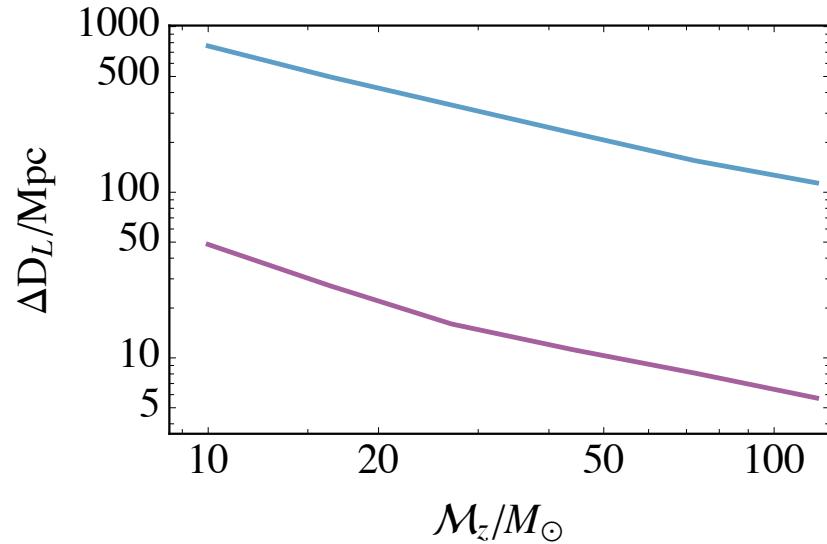




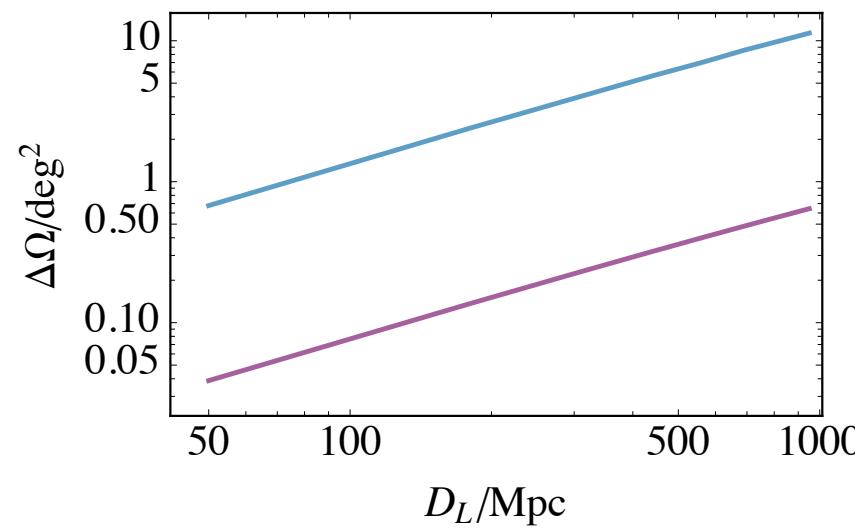
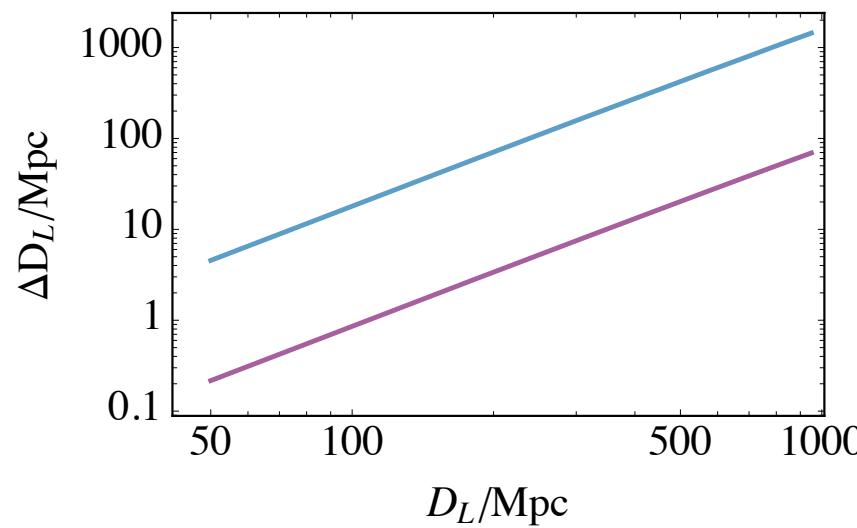
Measurement accuracy of GW waveform parameters for a GW150914-like source:

	AION 1 km	AEDGE	LIGO
$\Delta\Omega/\text{deg}^2$	45	0.073	179
$\Delta D_L/\text{Mpc}$	300	14	160
$\Delta\mathcal{M}_z/M_\odot$	6.7×10^{-4}	1.1×10^{-5}	2.0
Δq	0.42	0.010	0.19
$\Delta t_c/\text{s}$	12	0.38	$\mathcal{O}(0.01)$

$$q = 0.80, \quad D_L = 420 \text{ Mpc}$$



$$M_z = 30.7 M_\odot, \quad q = 0.80 M_\odot$$



Graviton mass

J. Ellis and V. Vaskonen, 2003.13480

Graviton mass changes the propagation of GWs,

$$E^2 = p^2 + m_g^2$$

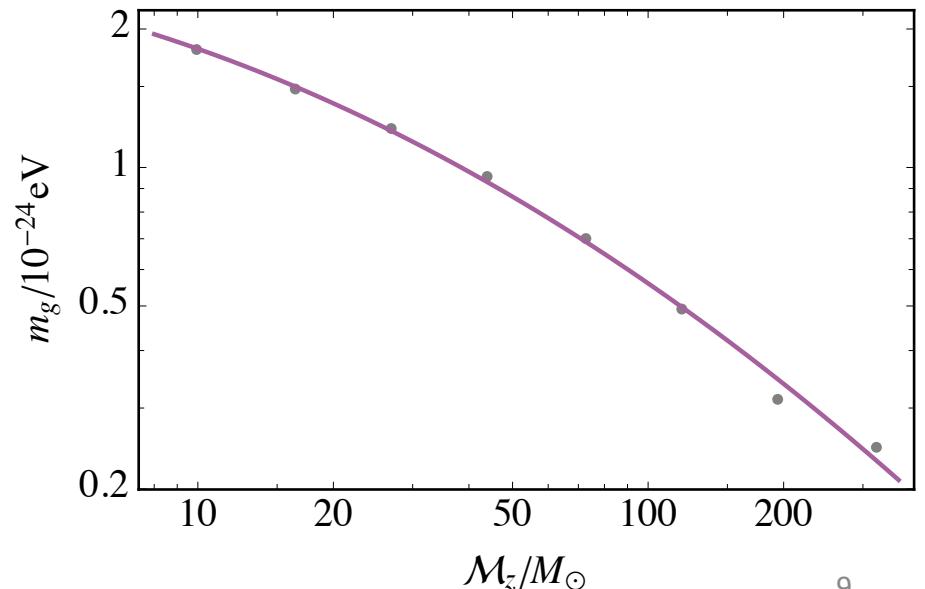
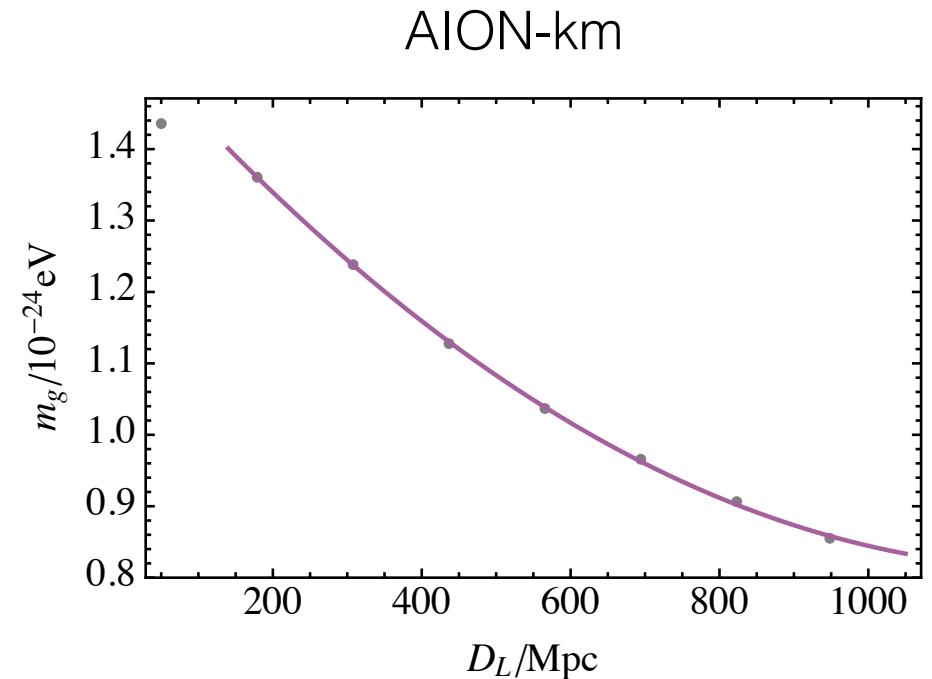
$$\Psi(f) \rightarrow \Psi(f) + \frac{m_g^2 D_0(z)}{4\pi(1+z)f}$$

LIGO constraint: $m_g < 4.7 \times 10^{-23} \text{ eV}$

AI sensitivities for a GW150914-like source :

AION-km: $m_g < 10^{-24} \text{ eV}$

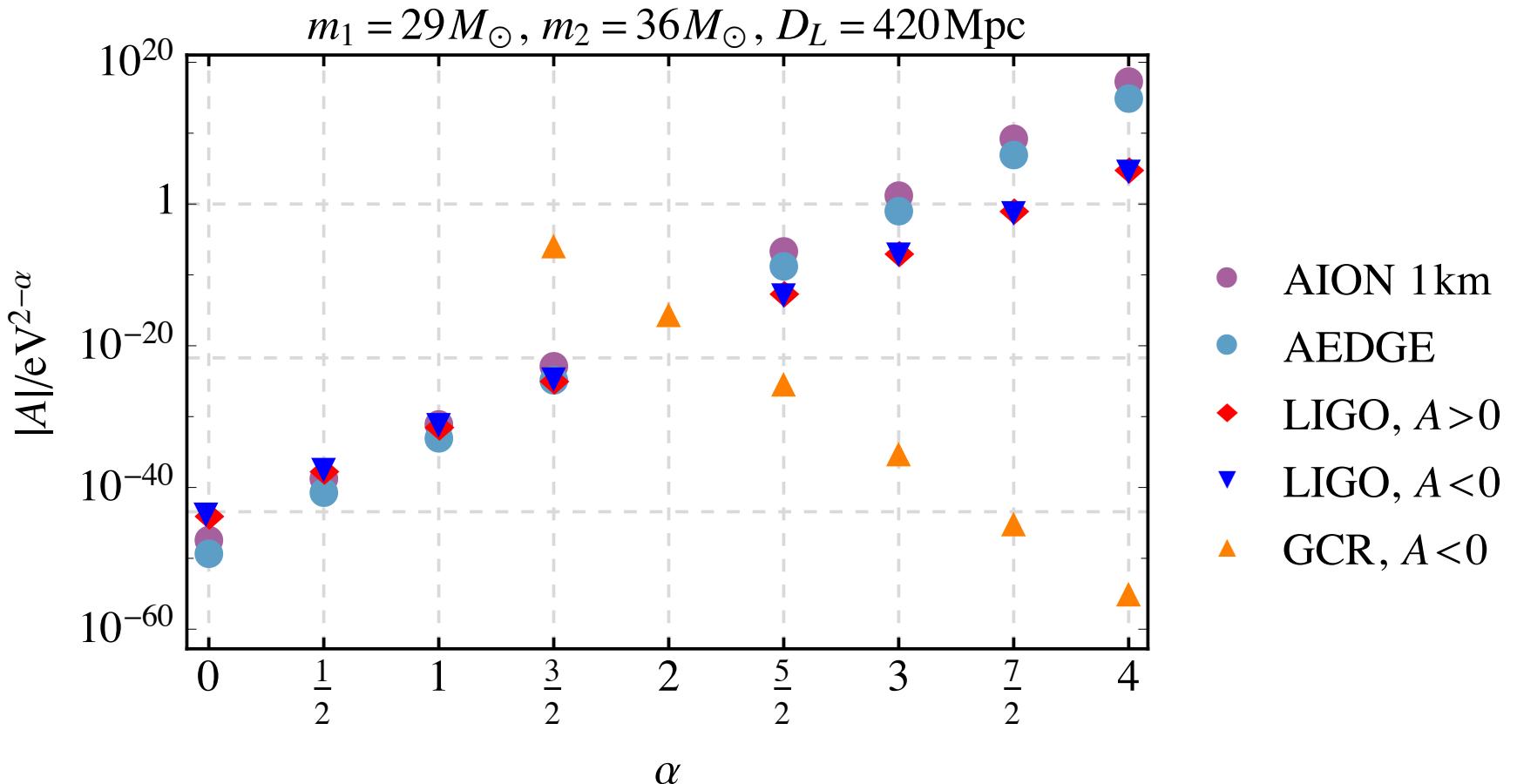
AEDGE: $m_g < 10^{-25} \text{ eV}$



Lorentz violation

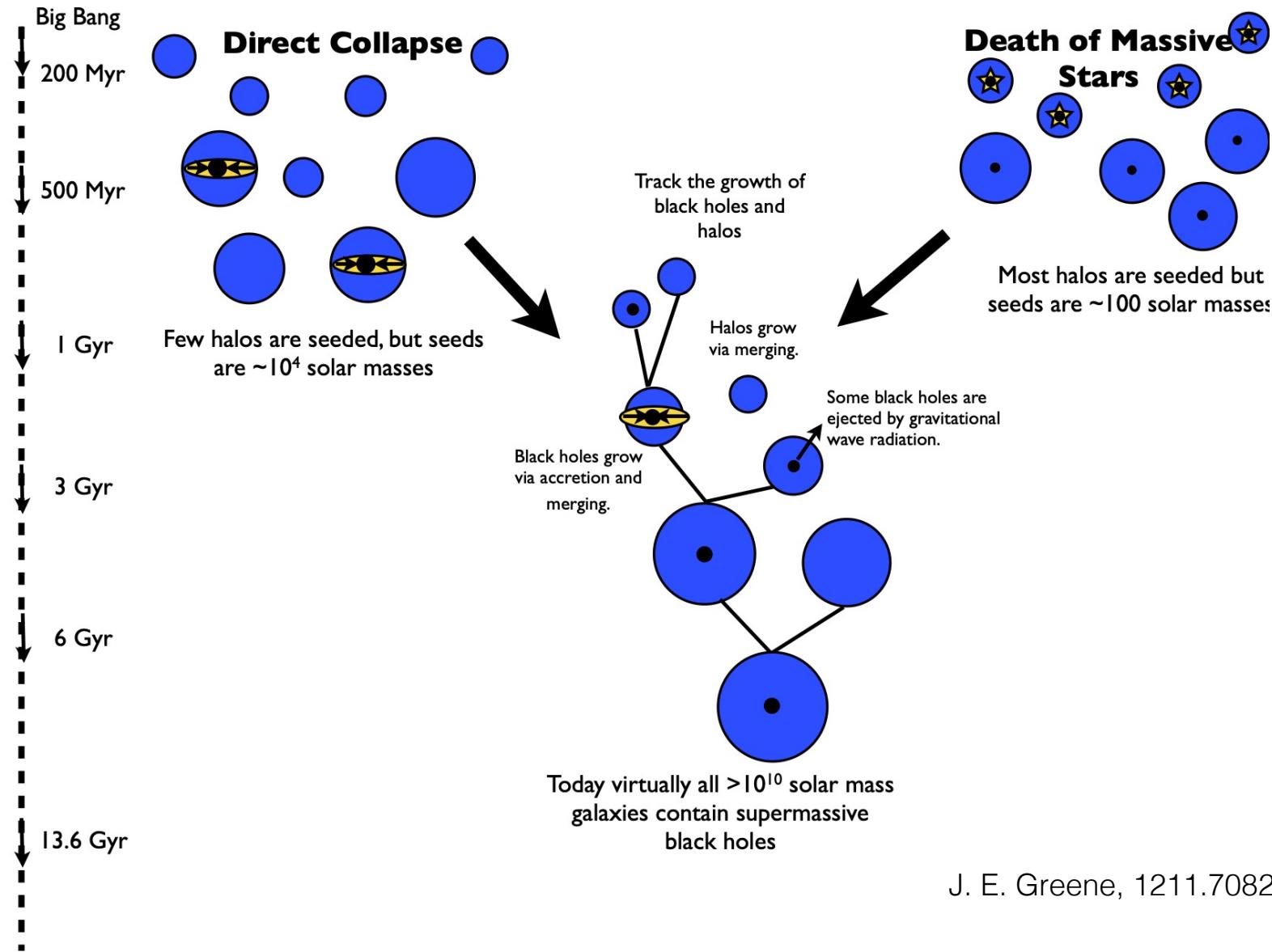
J. Ellis and V. Vaskonen, 2003.13480

Modified dispersion relation: $E^2 = p^2 + Ap^\alpha$, $\delta\Psi(f) \propto f^{\alpha-1}$



2. Intermediate mass black hole mergers

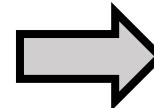
Formation of SMBHs



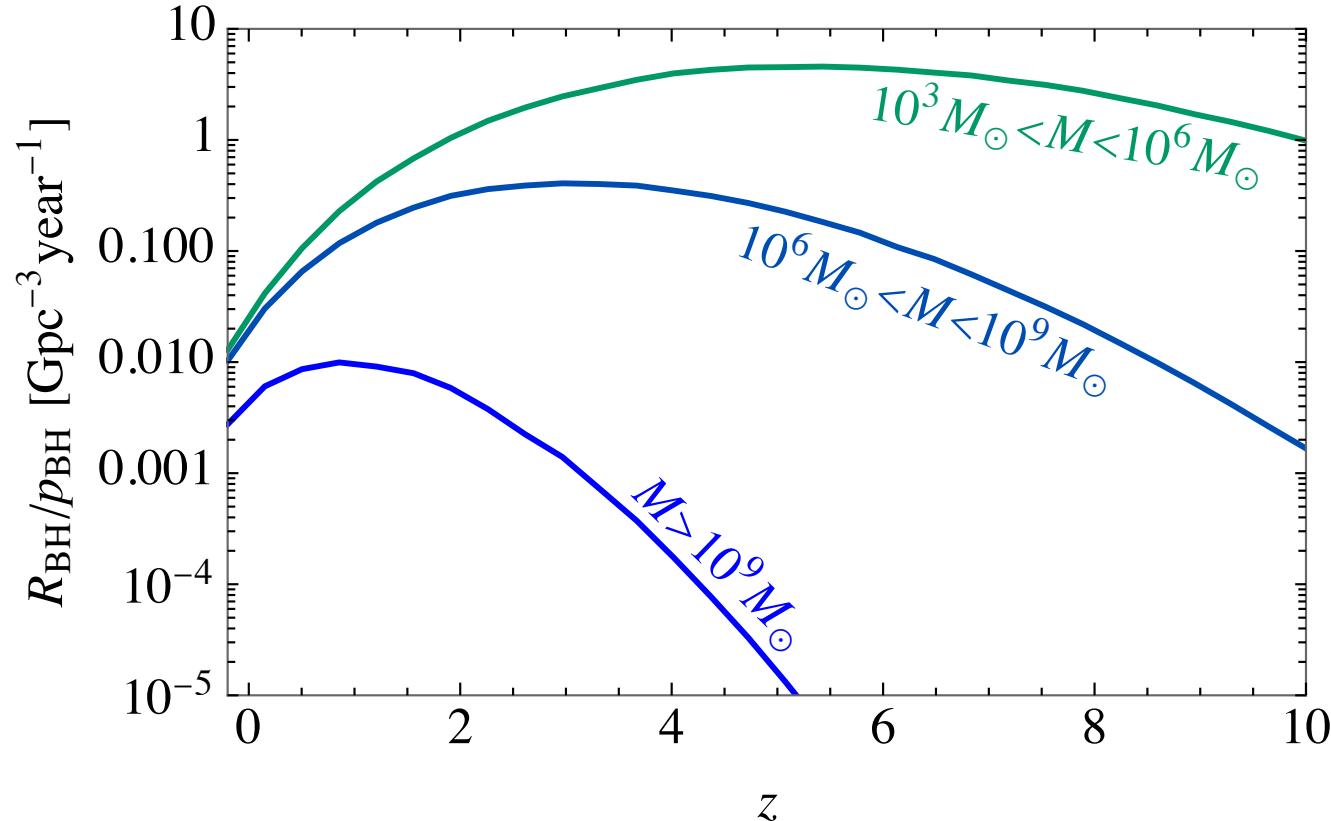
SMBH merger rate

J. S. B. Wyithe and A. Loeb, astro-ph/0211556

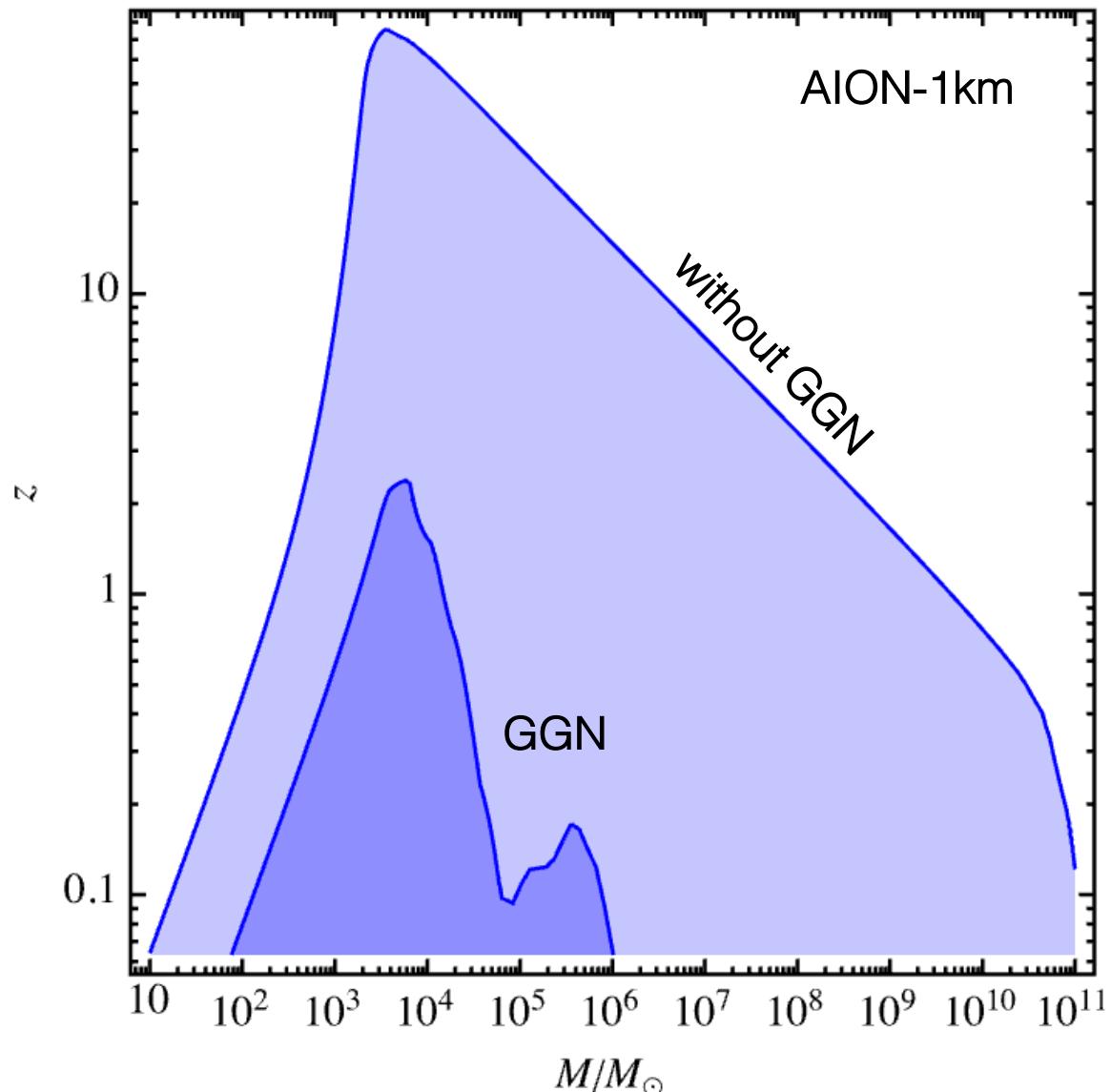
halo merger



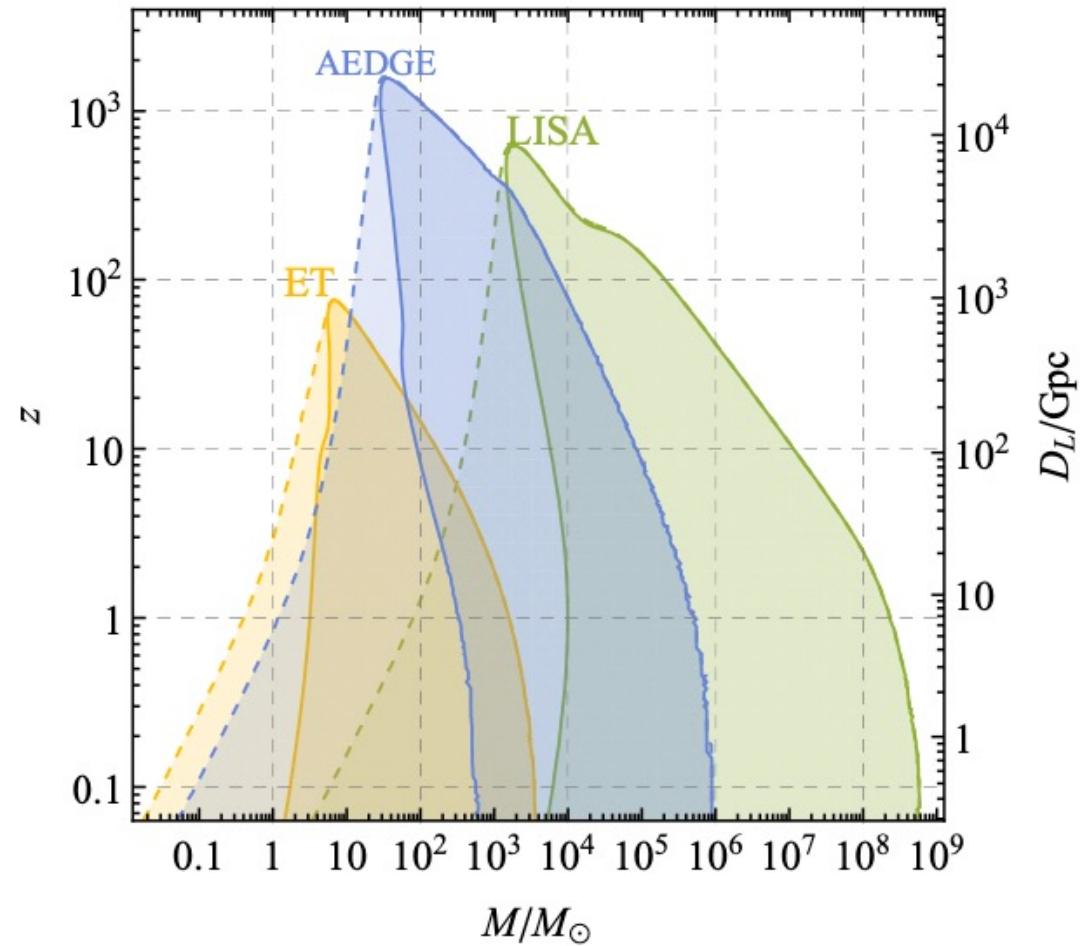
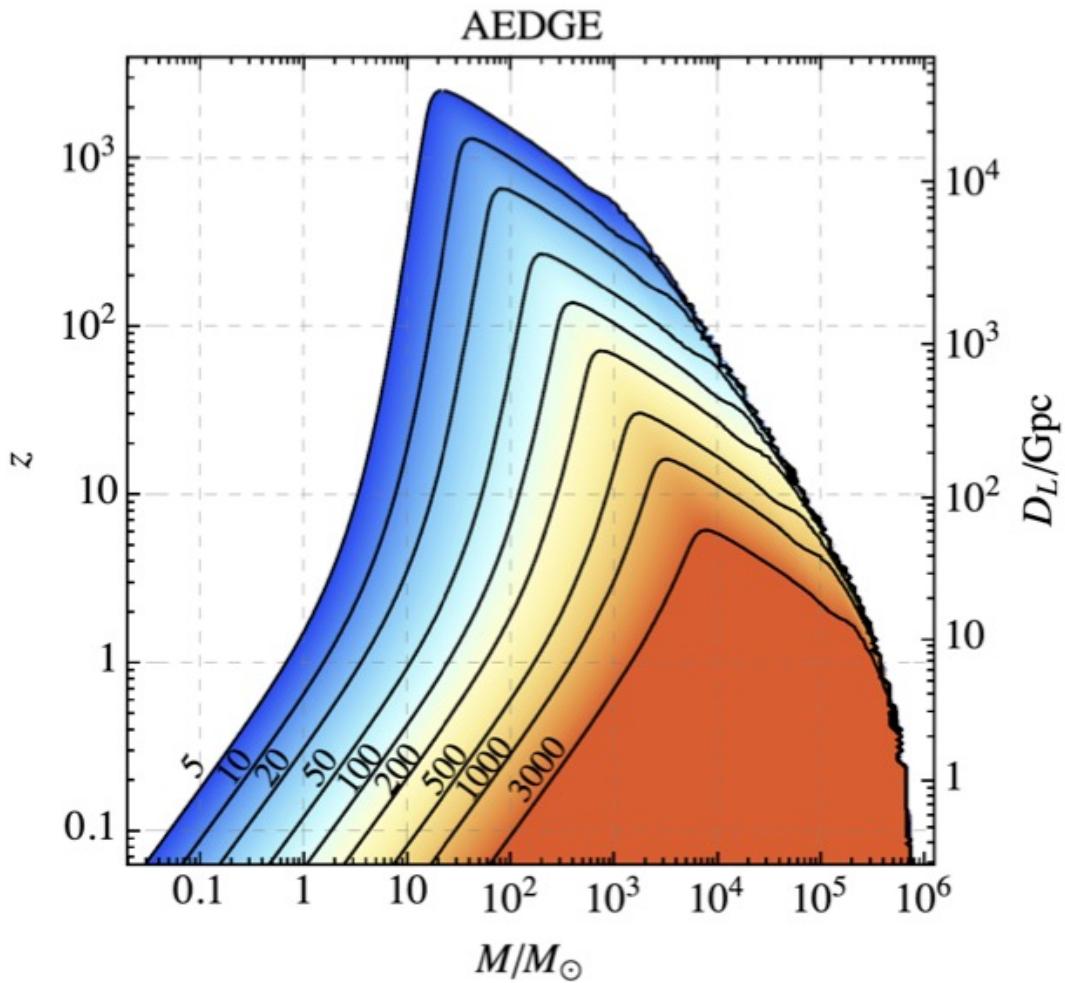
BH merger



Observing IMBH binaries

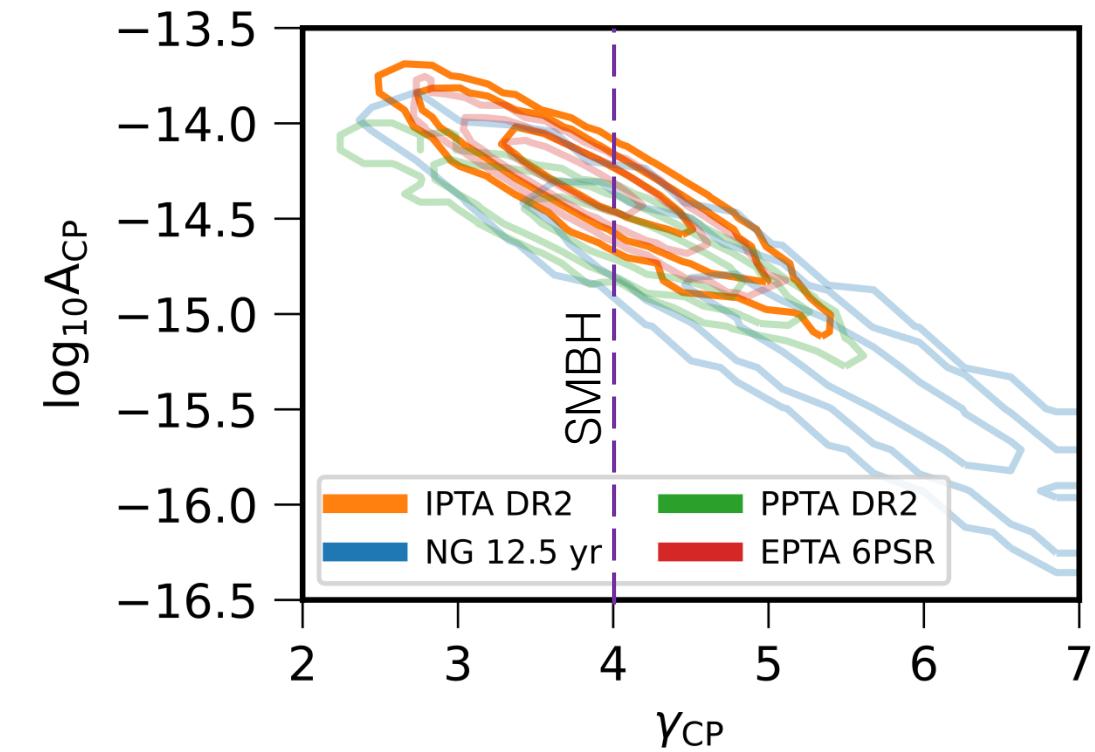
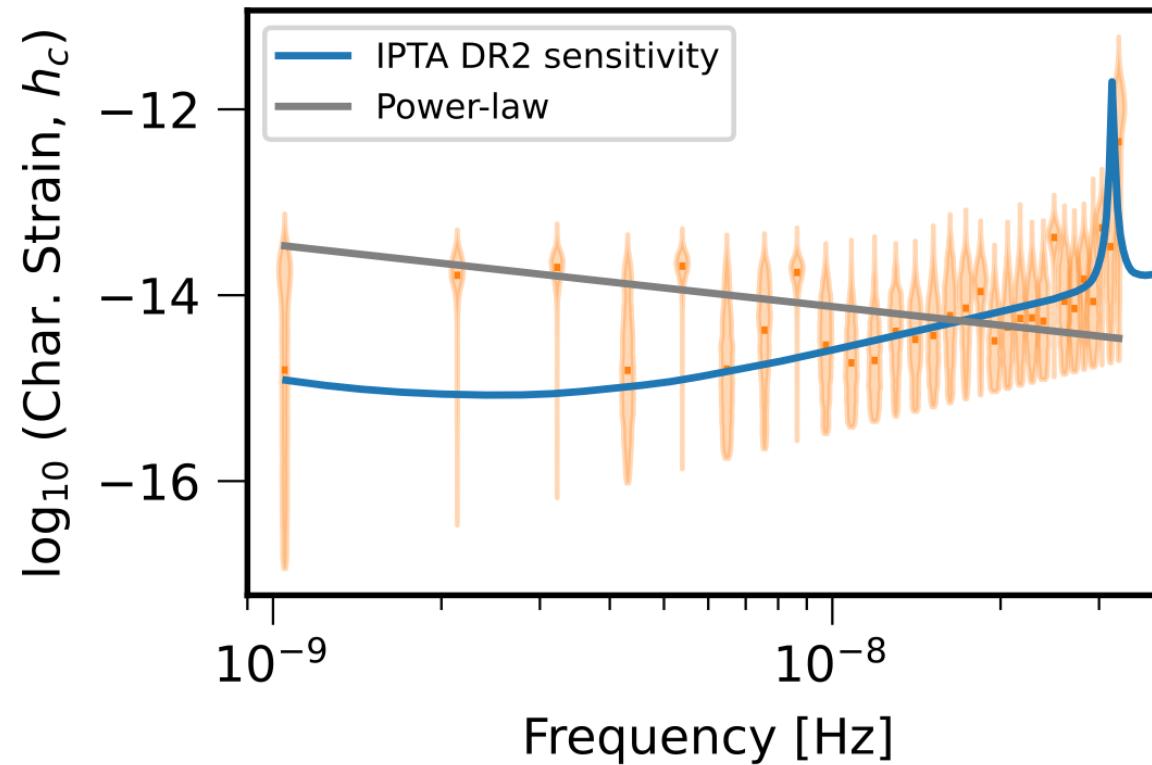


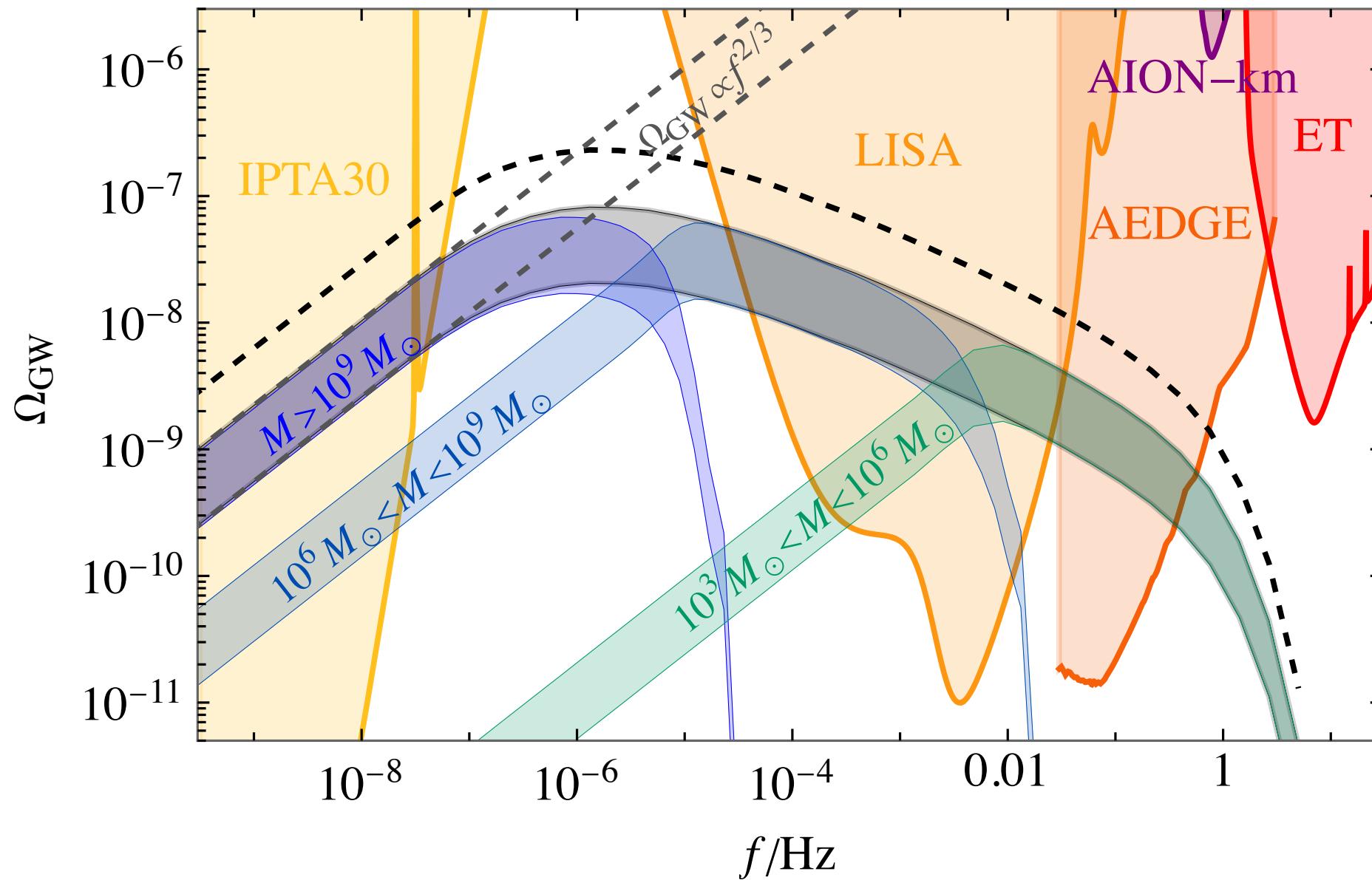
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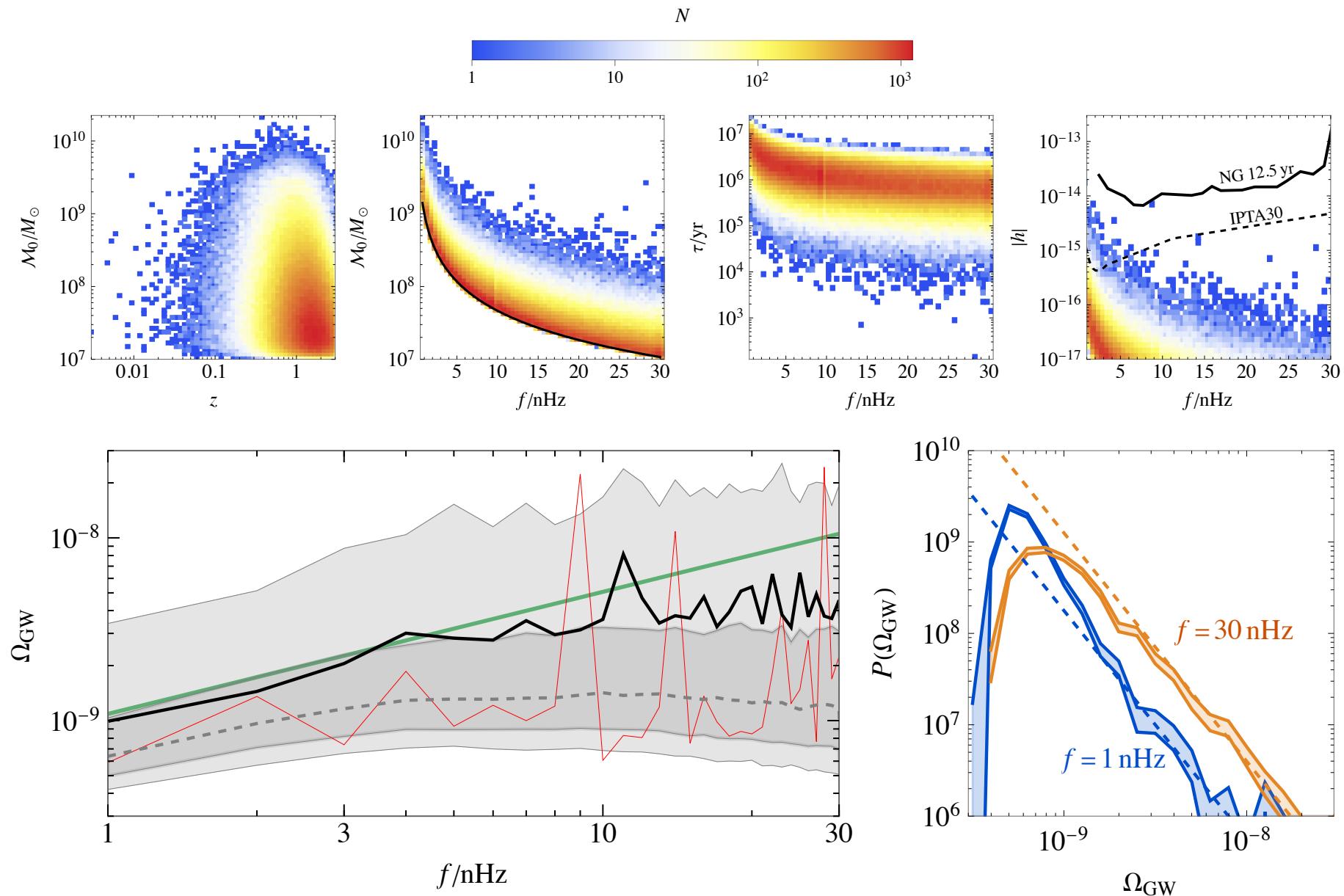


Potential GW observation by PTAs

NANOGrav, 2009.04496; PPTA, 2107.12112; EPTA, 2110.13184; IPTA, 2201.03980.



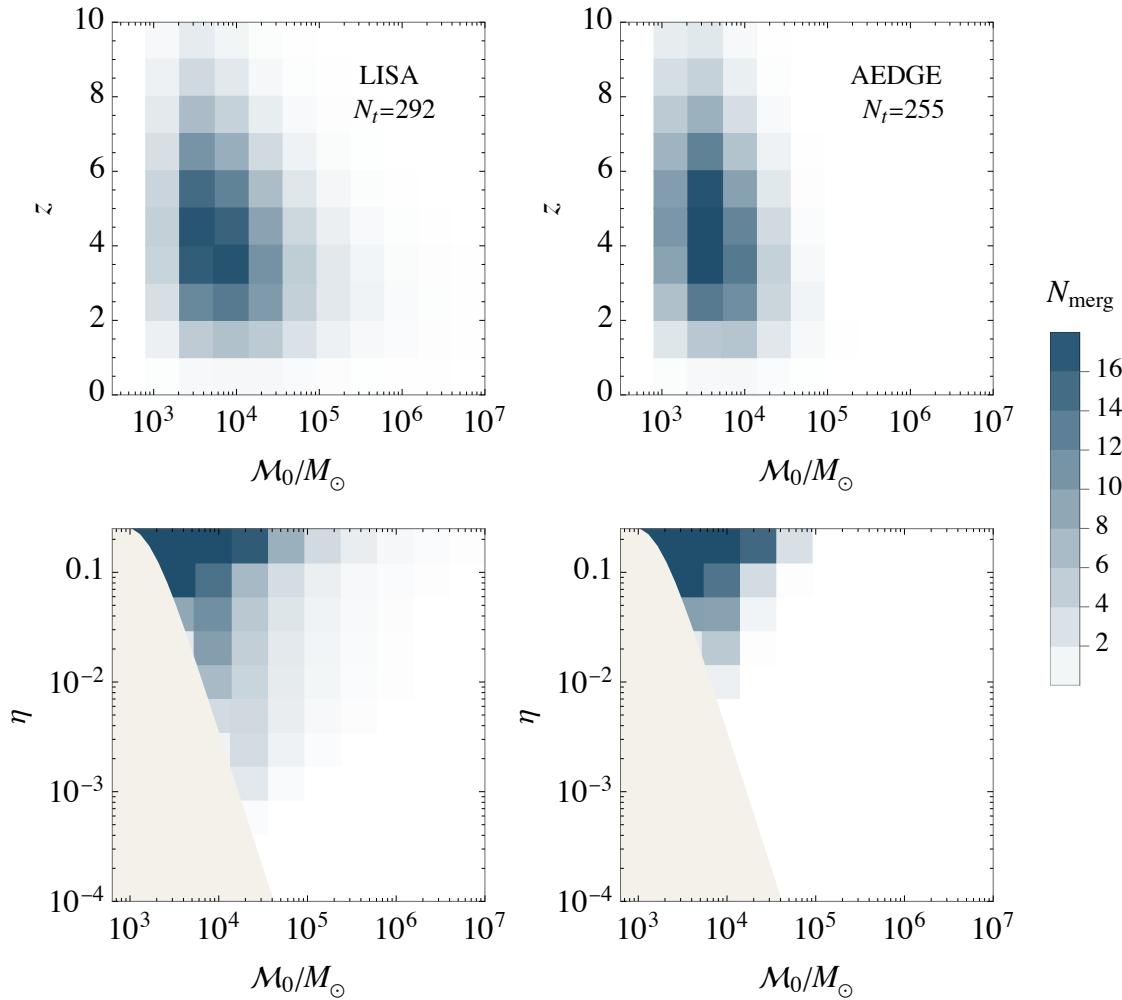




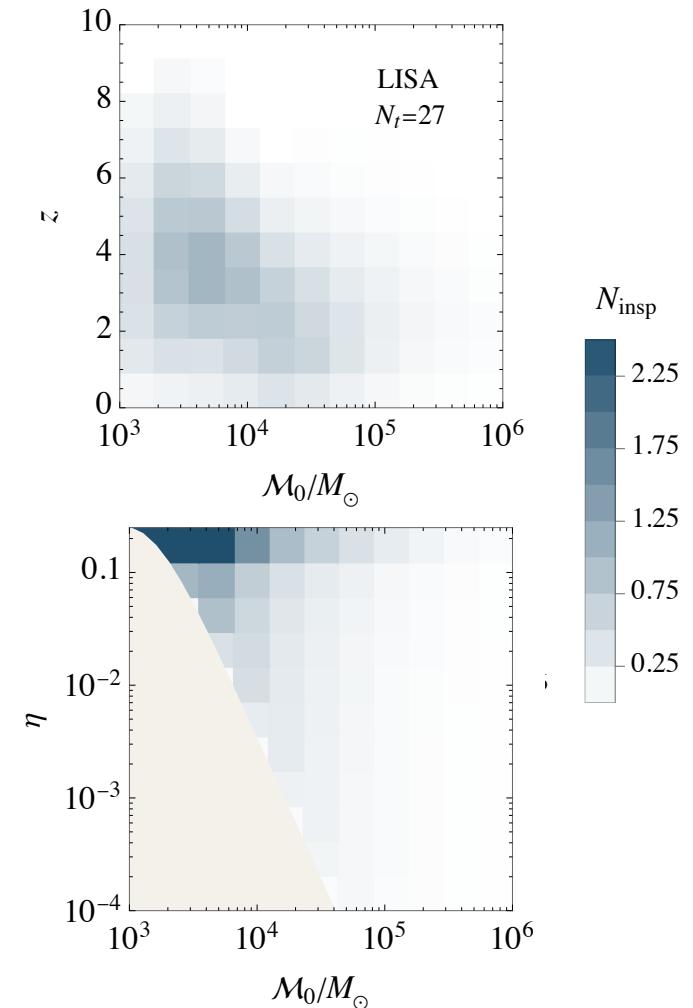
Prospects for future GW observatories

1. Short GW signals from BH binary mergers
2. Near-monochromatic GW signals from inspiralling BH binaries
3. GW background from BH binaries

Mergers:

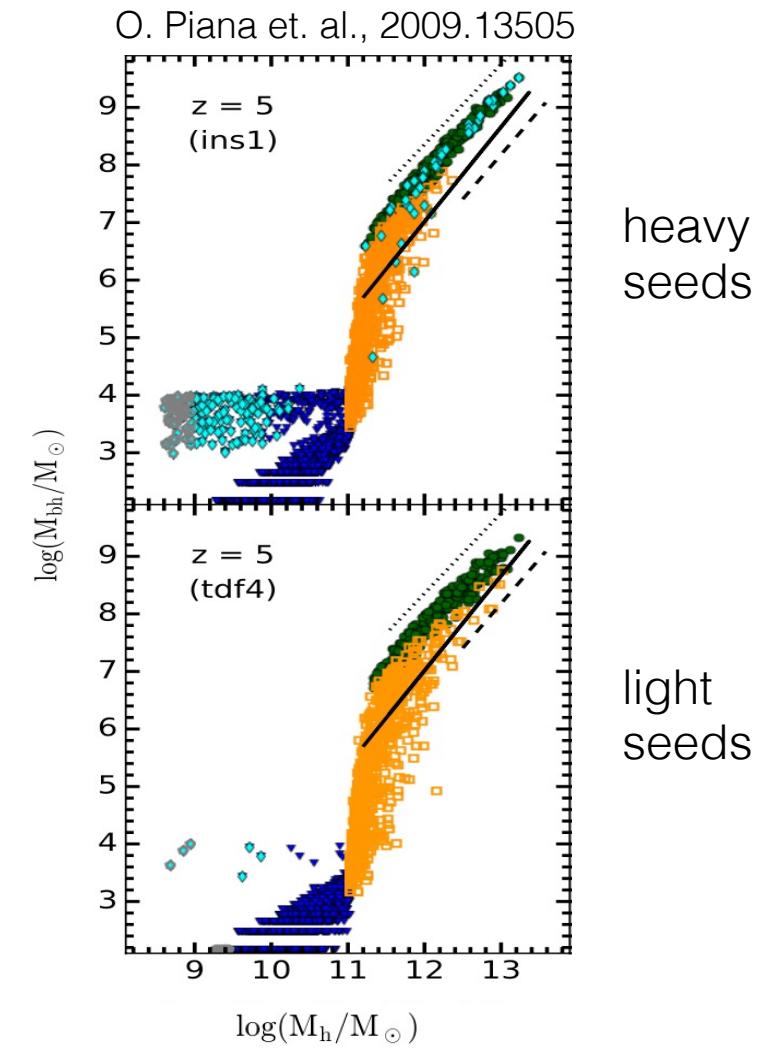
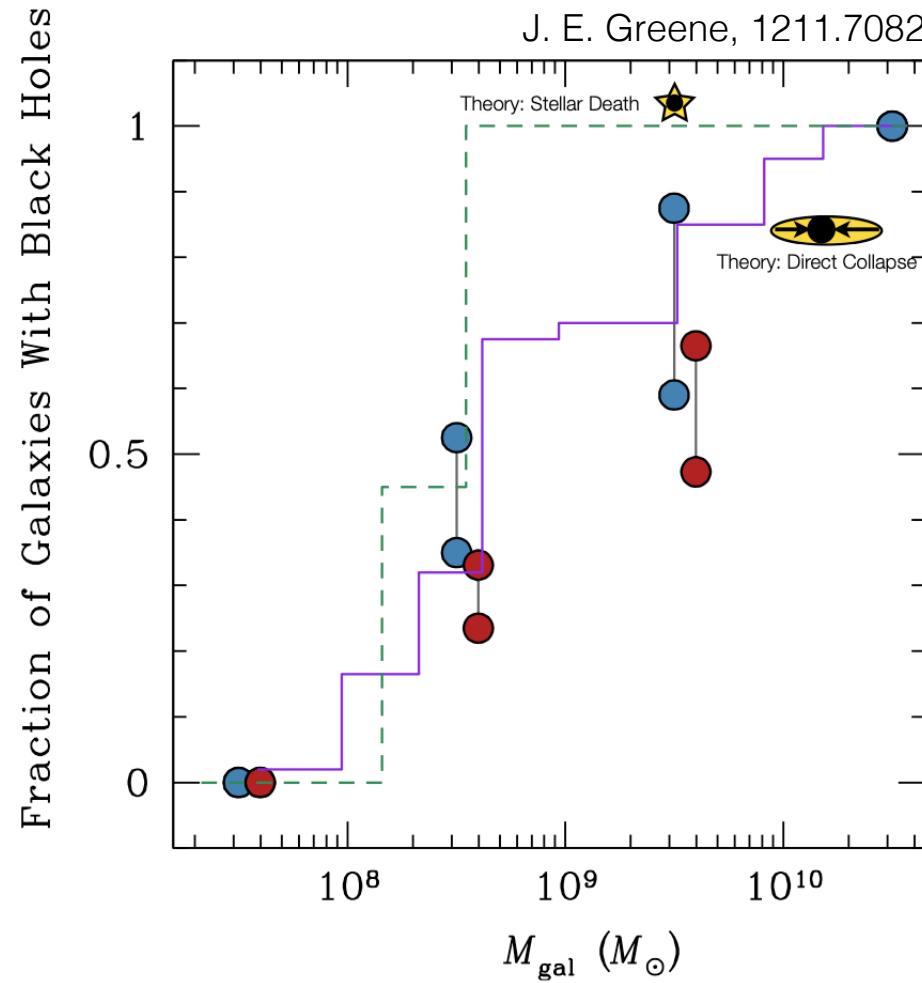


Inspirals:



Can we distinguish SMBH seed scenarios?

J. Ellis, M. Fairbairn, J. Urrutia and V. Vaskonen, work in progress.



Summary

1. AION and AEDGE are excellent for probing inspirals of stellar mass BH binaries and mergers of IMBH binaries.
2. By observing the inspiral for several months, they can accurately locate the stellar mass binaries.
3. They can also probe e.g. graviton mass and Lorentz violation.
4. The formation of SMBH binaries through halo mergers leads to a population of IMBH binaries.
5. AEDGE may be able to tell whether the SMBH formation is dominated by heavy or light seeds.