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Impact of LIGO-Virgo binaries on gravitational wave background searches

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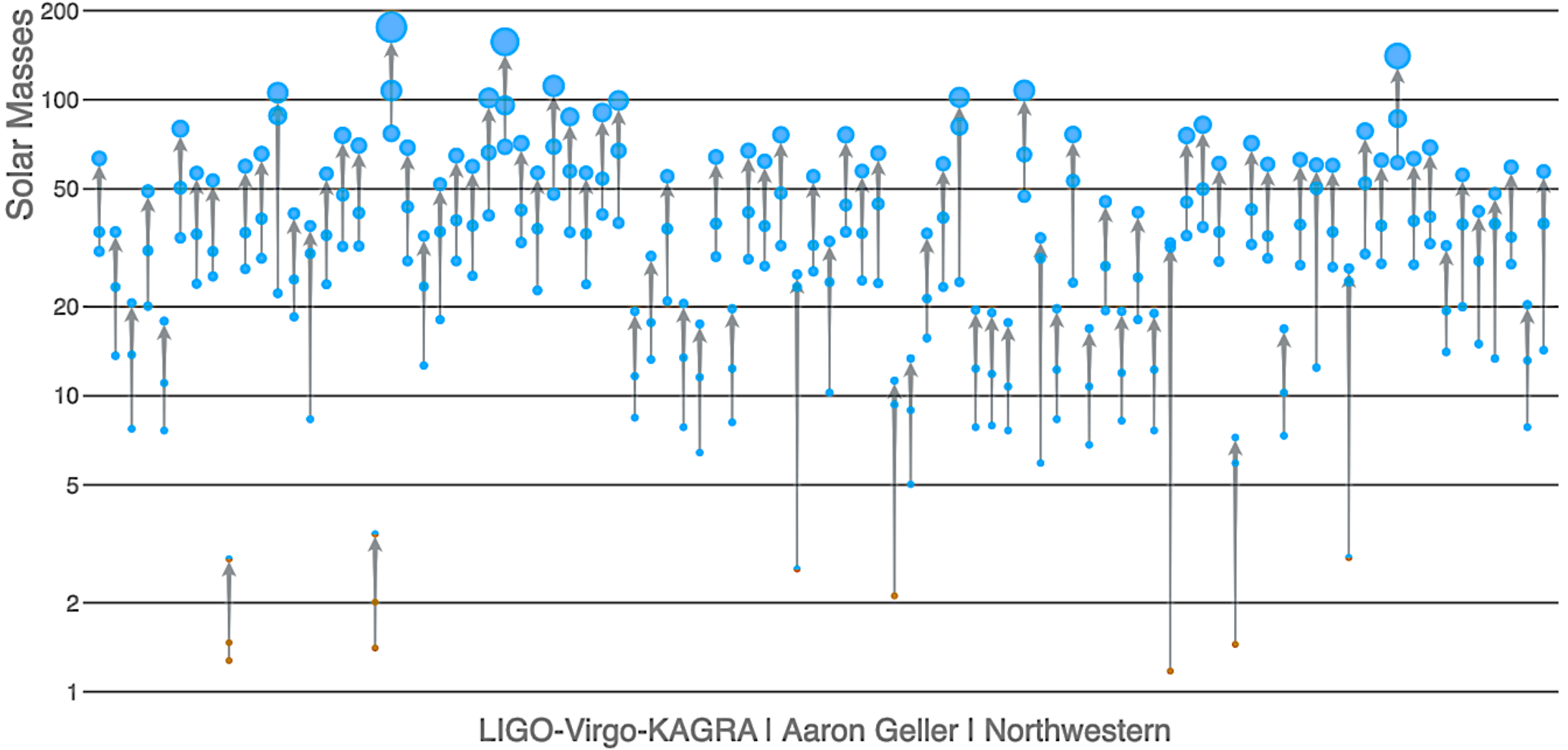
9th LISA Cosmology Working Group Workshop

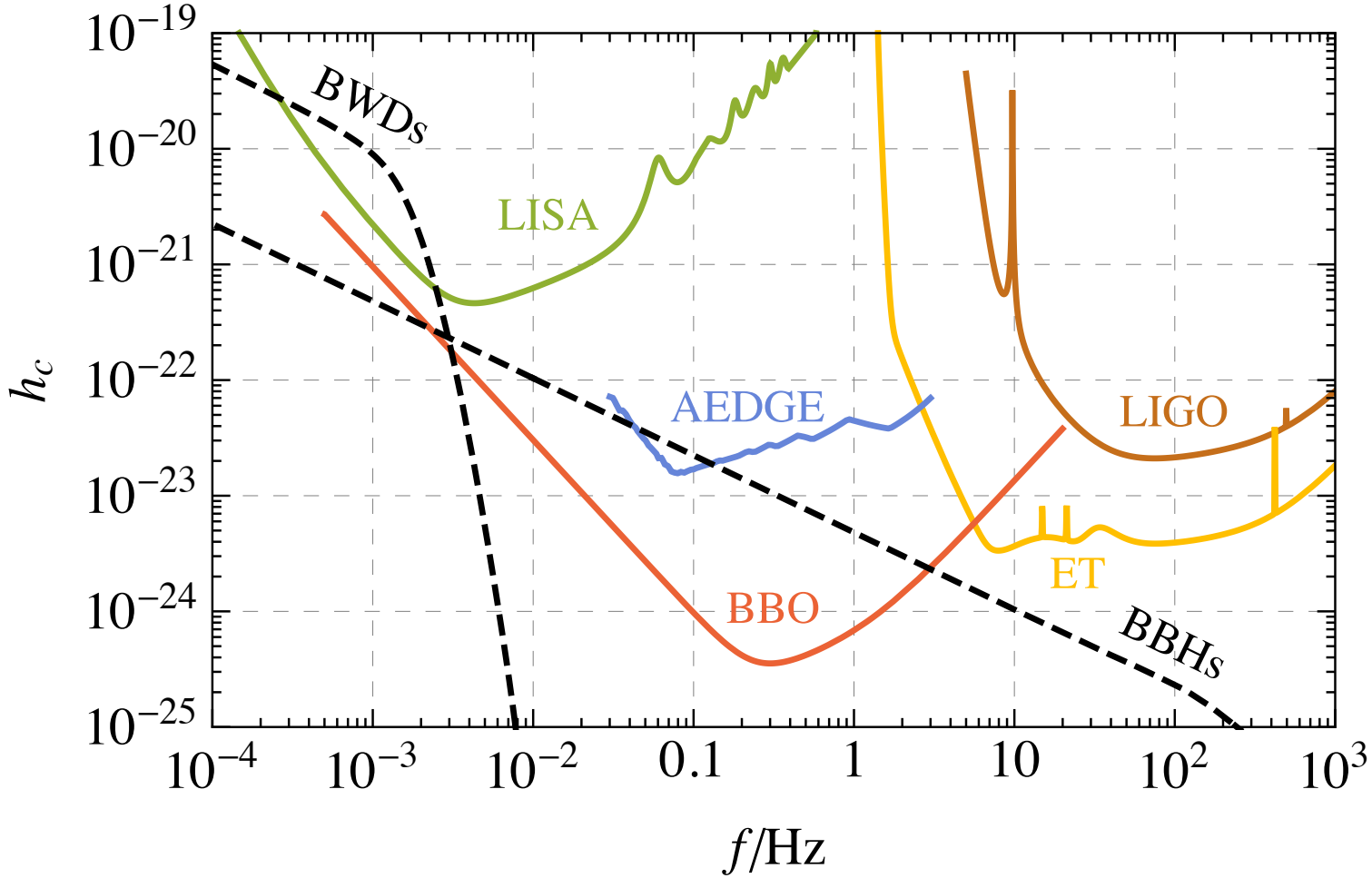
Gravitational wave signals

LIGO-Virgo has so far observed 90 CBC events:



Foregrounds

Unresolvable compact object binaries constitute a GW foreground.



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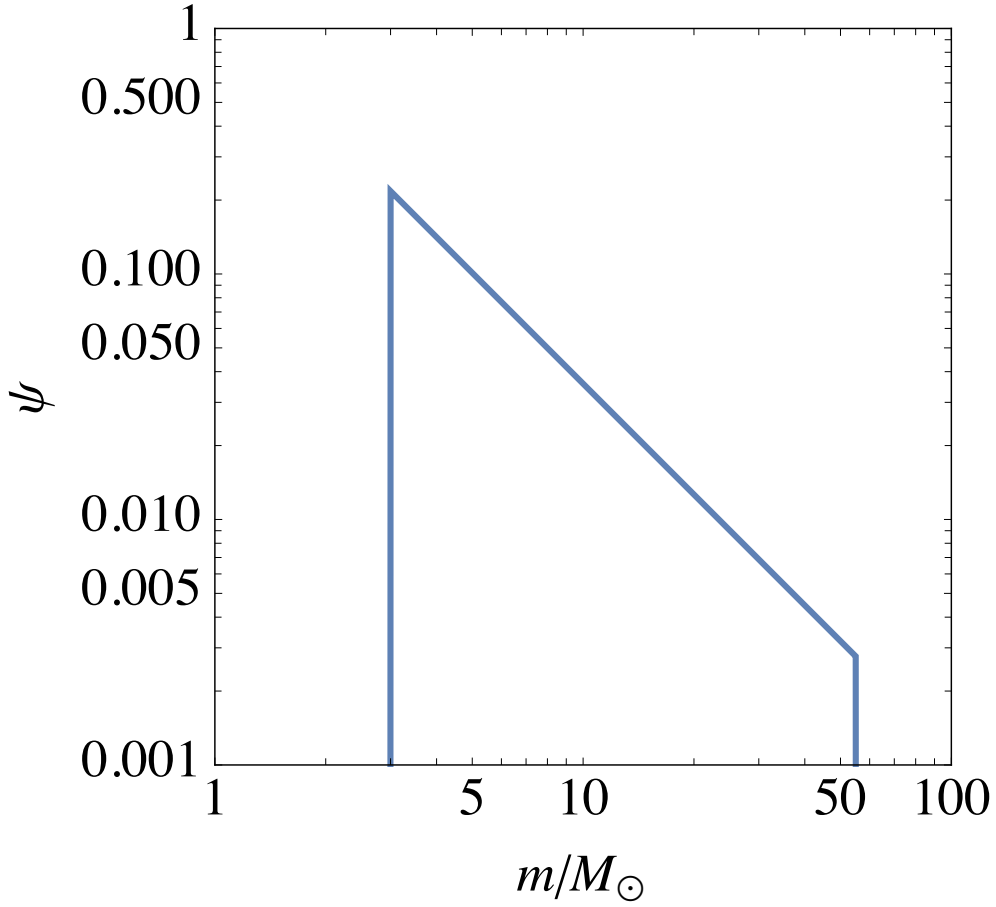
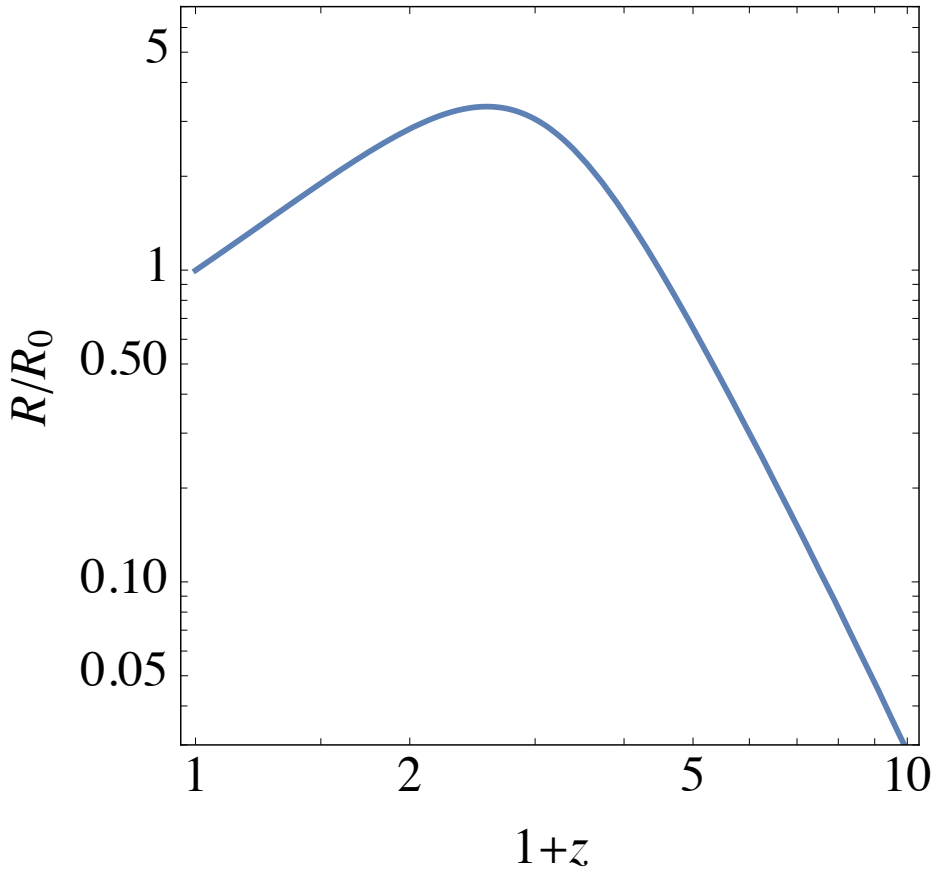
LIGO-Virgo BH population

truncated power-law mass distribution:



merger rate that follows the star formation rate:



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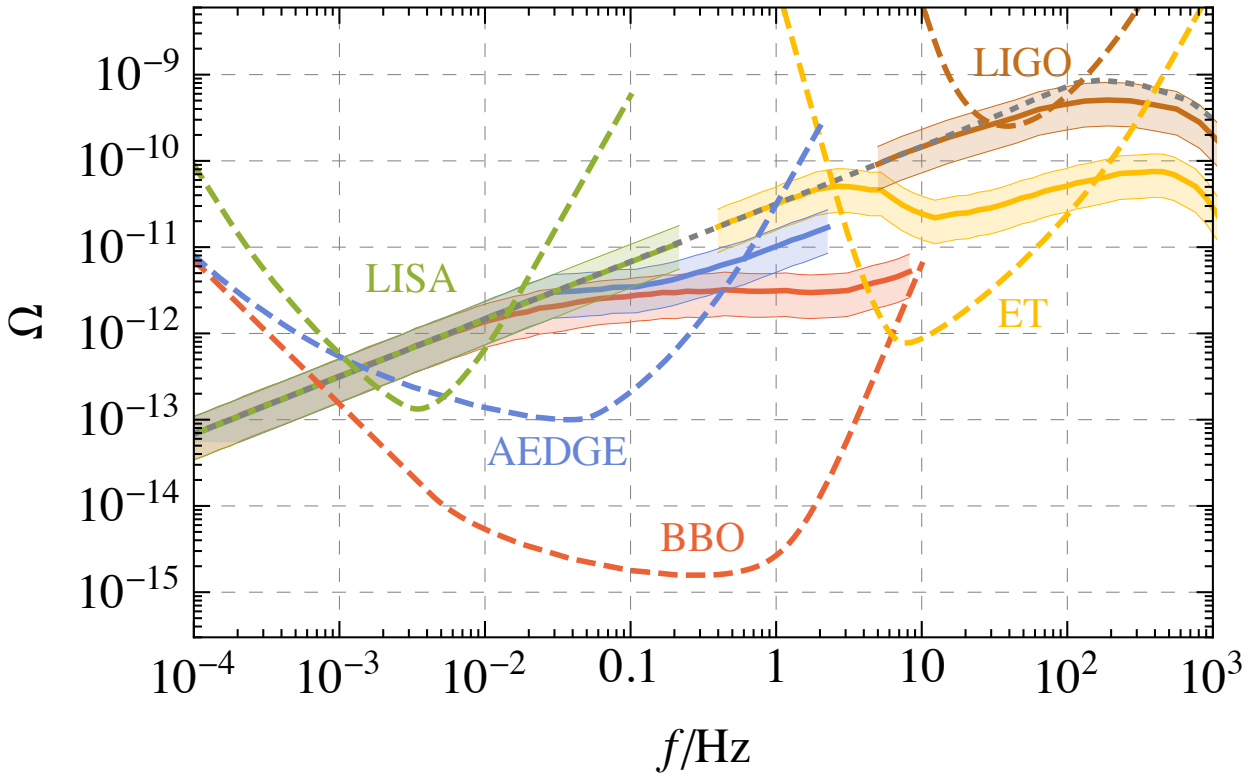
GW foreground from BH binaries

GWs from unresolvable binaries: $$\Omega_{\rm BBH}(f) = \int \frac{{\rm d}V_c}{1+z}{\rm d}R(z)\frac{1}{\rho_c}\frac{{\rm d}\rho_{\rm GW}}{{\rm d}f}\left[1-p_{\rm det}(f)\right]$$

Uncertainties in the BBH foreground:

$$\Omega_{\rm BBH} \propto R_0$$

$$R_0 = 10^{+6}_{-5}\,{\rm Gpc}^{-3}{\rm yr}^{-1}$$



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Detectability of the GW background

background foregrounds instrumental noise

$$\Omega_{\rm GW}(f) = \Omega \left(\frac{f}{f_{\rm ref}}\right)^{\alpha} + \Omega_{\rm BBH}(f) + \Omega_{\rm BWD}(f) + \Omega_{\rm instr}(f)$$

Use Fisher analysis to estimate the detectability of the background:

$$\sigma_j^2 = \Gamma_{jj}^{-1} \qquad \Gamma_{ij} = \mathcal{T} \int {\rm d}f \, \frac{\partial_i \Omega_{\rm GW} \partial_j \Omega_{\rm GW}}{\Omega_{\rm n}(f)^2}$$

Calculating the Fisher matrix only in Ω gives

$$\frac{\sigma_\Omega}{\Omega} = \frac{1}{\sqrt{\Omega^2 \, \Gamma^{-1}_{\Omega\Omega}}} < \frac{1}{{\rm SNR}_c} \qquad \text{if} \qquad {\rm SNR} > {\rm SNR}_c$$

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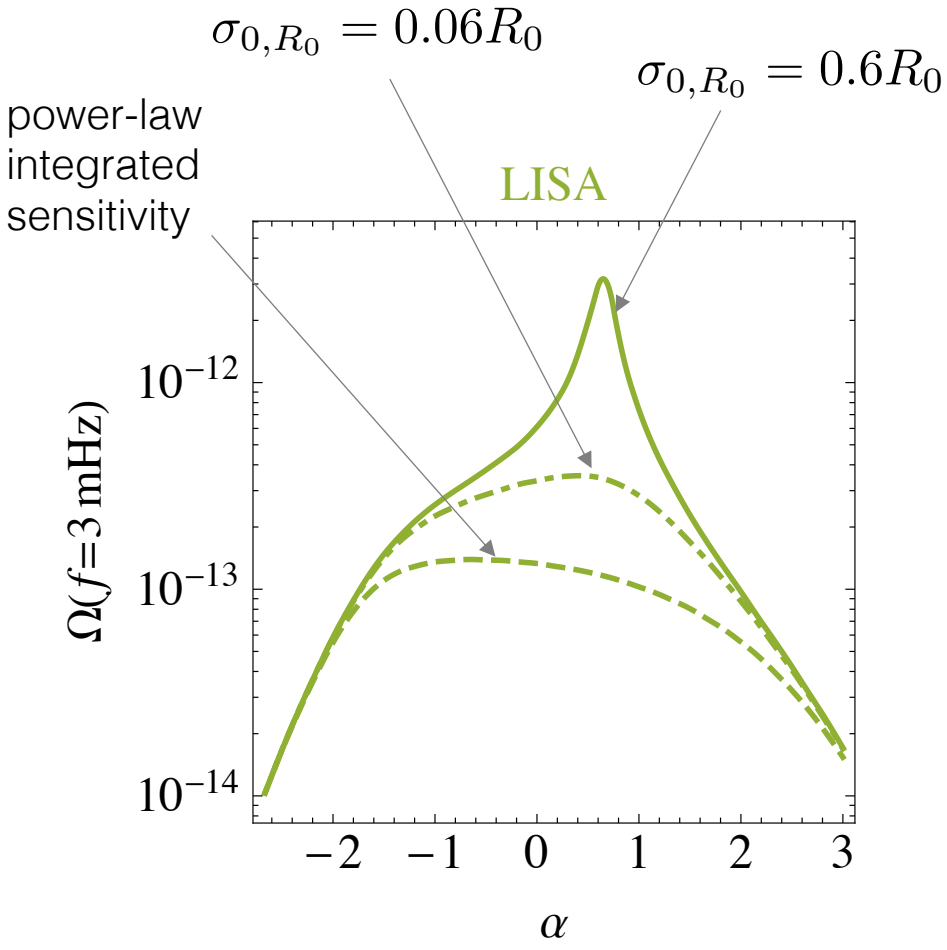
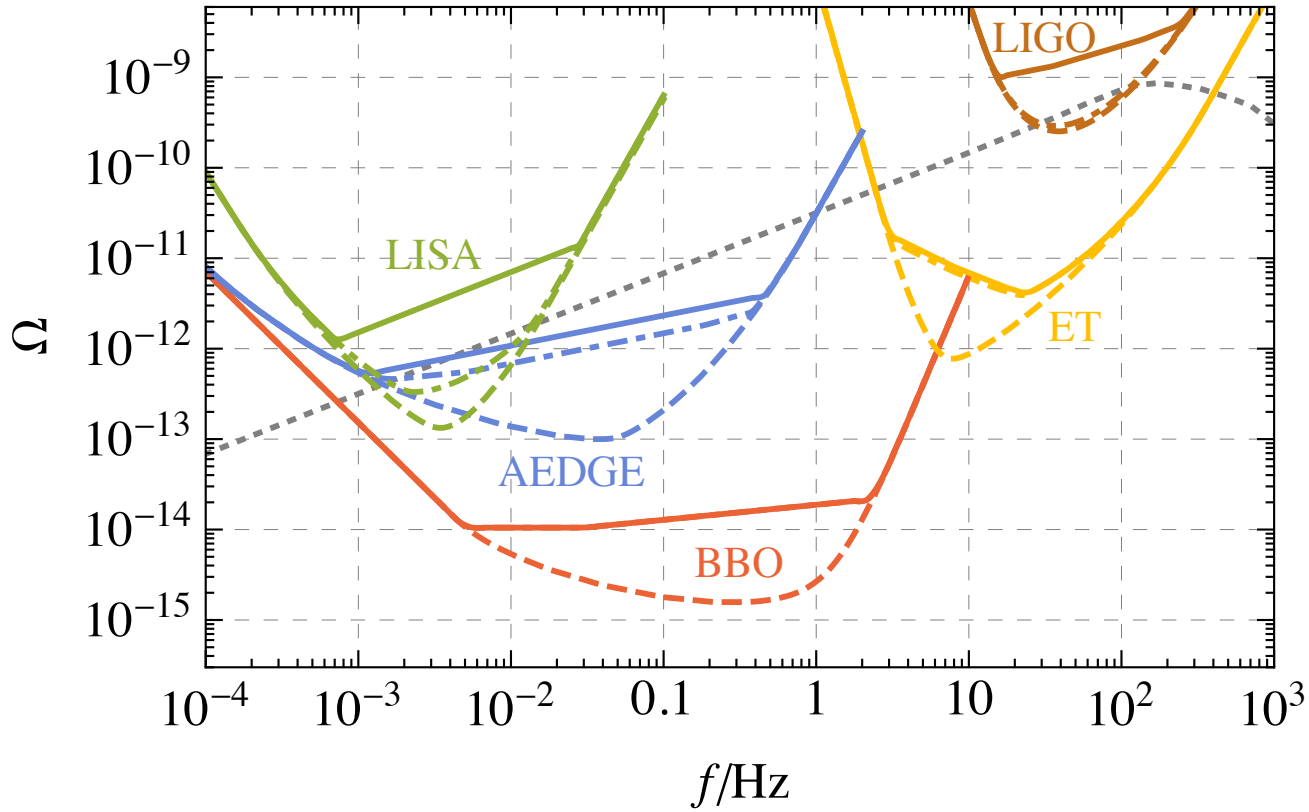
Detectability of the GW background





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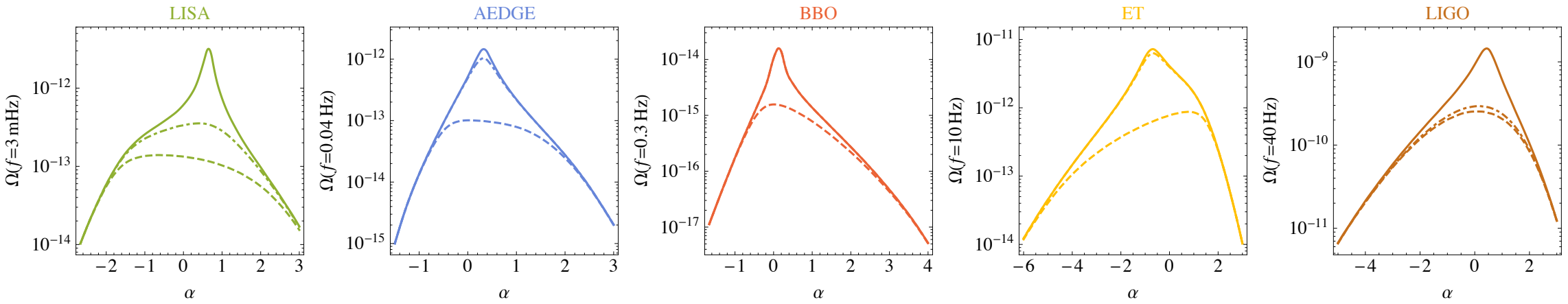
Summary

- The BH binary population probed by LIGO-Virgo generates a GW foreground.
- Part of that foreground can be mitigated as some of the binary signals can be resolved individually.
- The foreground masks the GW background and significantly impacts its detectability.



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