Astrophysical uncertainties in the SGWB from stellar mass binary mergers

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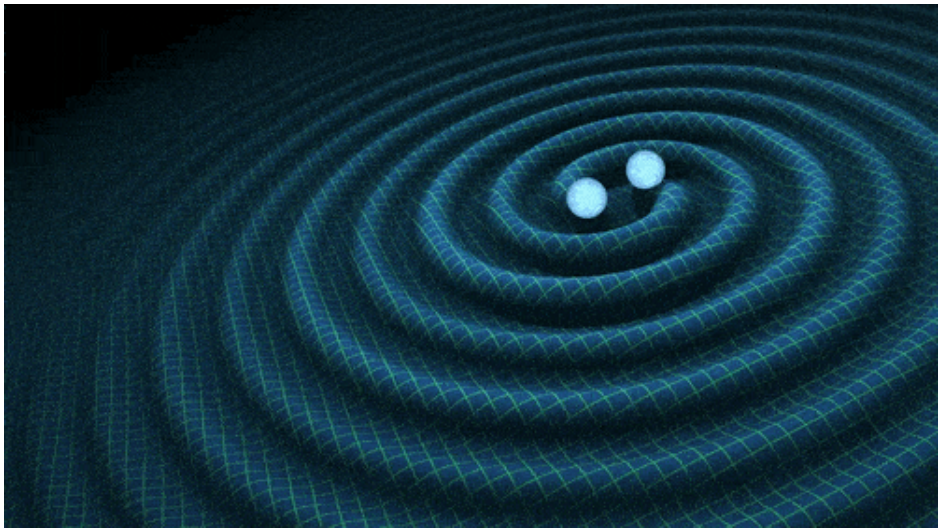
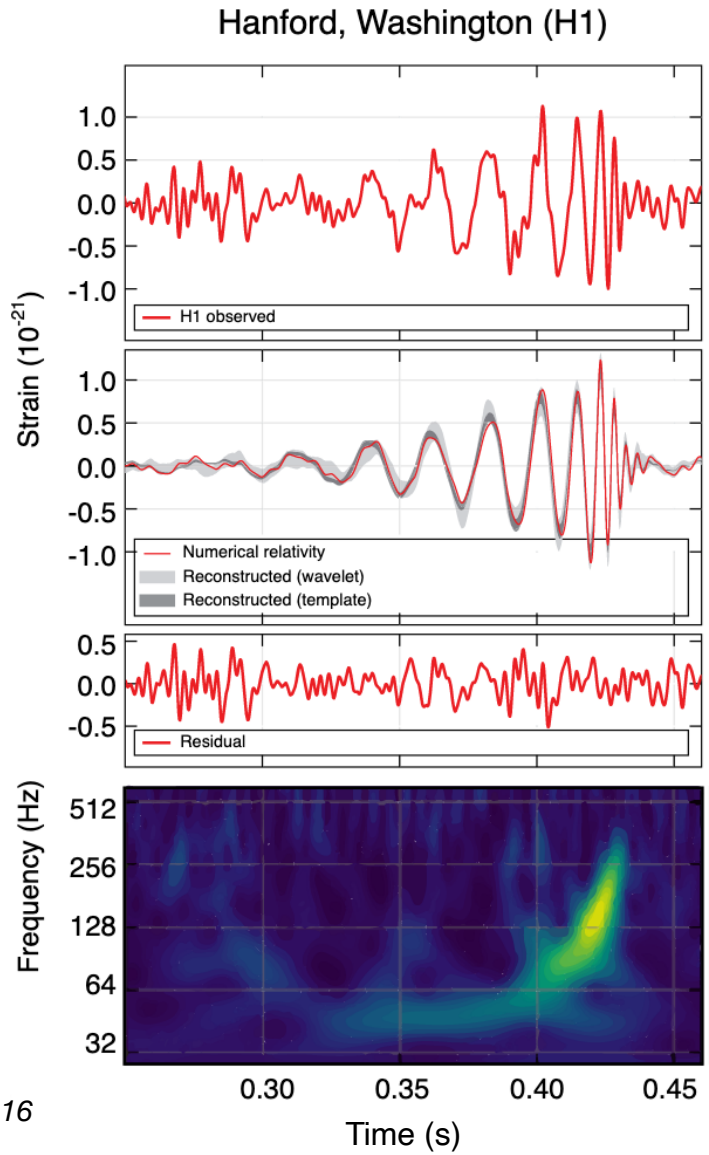
Institut d'Astrophysique de Paris, journées PNHE, 07/09/2023

Gravitational waves

- ~ **90 BBHs** mergers detected
- ~ **2 BH-NS** mergers detected
- ~ **2 BNS** mergers detected





Observation of Gravitational Waves from a Binary Black Hole Merger,
B.P. Abbott et al. , Phys. Rev. Lett. 116, 061102 – Published 11 February 2016

Stochastic GW Background

There are two types of stochastic backgrounds:

- The **astrophysical background** (unresolved superposition)
- The **cosmological background** (produced in the primordial universe)

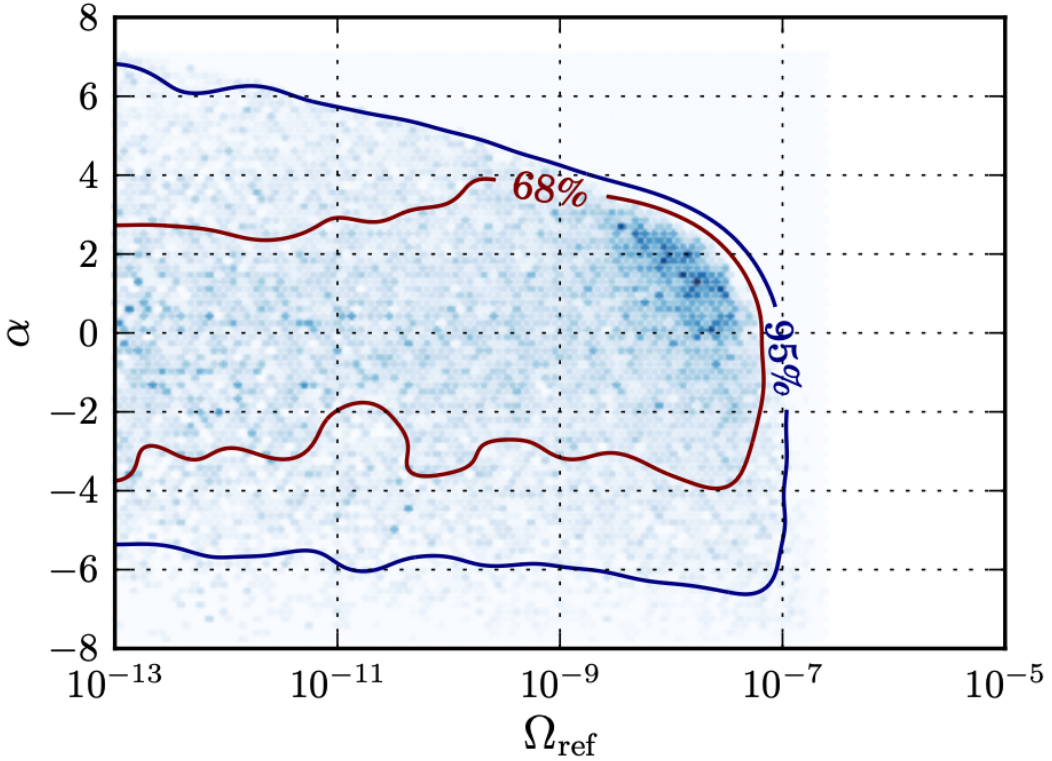
$$\Omega_{\mathrm{GW}} = \frac{1}{\rho_c} \frac{\mathrm{d}\rho_{\mathrm{GW}}}{\mathrm{d}\log f}$$

We are interested in the stochastic **astrophysical** background produced by **compact binaries** for **LIGO/Virgo** and **LISA**.

SGWB observational upper limit

—> No evidence for a SGWB from stellar-mass sources.

—> $\Omega_{GW} < 4.8 \times 10^{-8}$ at 25 Hz, 95% credible upper limit level for a background of compact binary mergers.

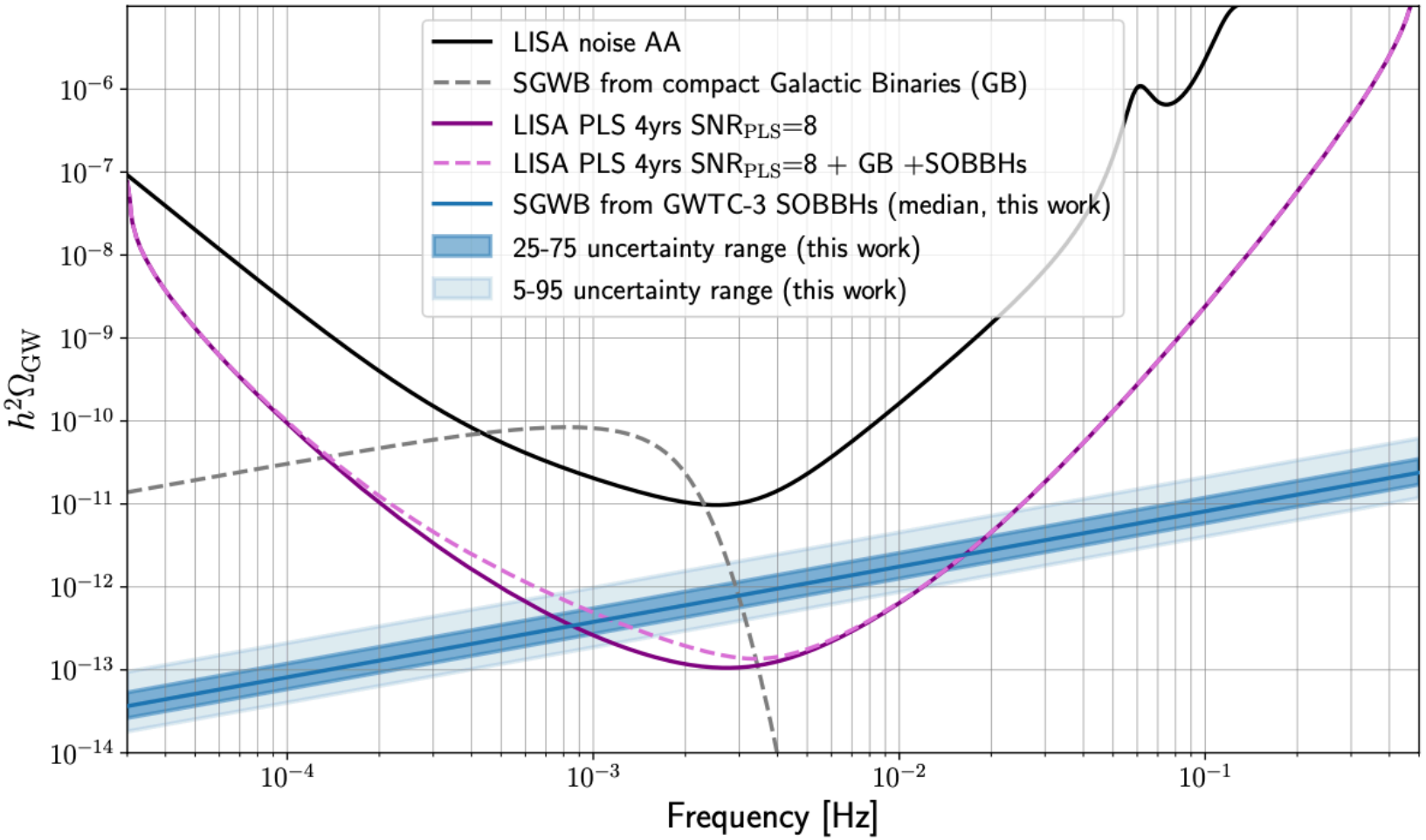


$$\Omega_{\rm GW}(f) = \Omega_{\rm ref}\left(\frac{f}{f_{\rm ref}}\right)^{\alpha}$$

Posterior distribution of the amplitude Ω_{ref} and the slope α of the SGWB, using a uniform prior.

LVK collaboration, 2019, PRD, 100, 061101

SGWB predictions



In blue, the median value for the stellar-mass BBH SGWB estimated from LVK constraints.

Babak et al. (2304.06368)

Merger rate of compact binaries

$$R_{\rm merg}(t) = \int_0^{Z_{\rm max}} \int_{t_{d,\rm min}}^{t_{d,\rm max}} \alpha(Z)\, \psi(t - t_d)\, P(t_d|Z)\, P(Z|t - t_d)\, dt_d\, dZ$$

Lehoucq et al. (2306.09861)

Merger rate of compact binaries

Mass efficiency

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Star formation rate

Lehoucq et al. (2306.09861)

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Star formation rate

Time delay distribution

Lehoucq et al. (2306.09861)

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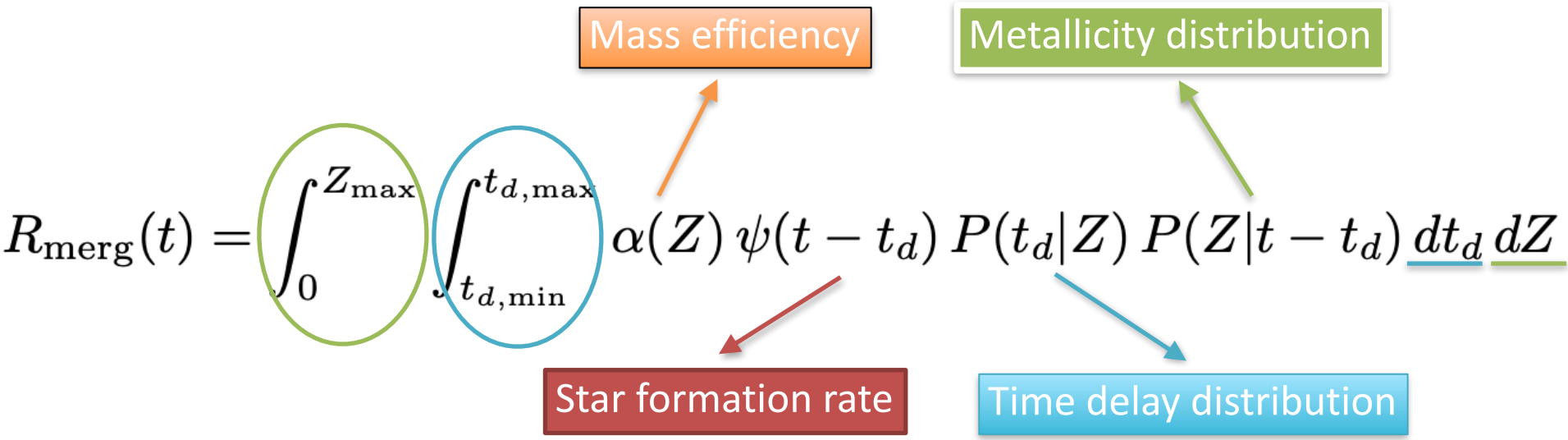

Lehoucq et al. (2306.09861)

Merger rate of compact binaries

Mass efficiency

Metallicity distribution

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Star formation rate

Time delay distribution

SFR from Vangioni et al. (MNRAS, 447, 2575)

- Baseline model
- Baseline_delays model → $P(t_d) \propto t_d^{-1}$
- Metallicity cut model → $Z_{\rm cut} = 0.1\, Z_\odot$

Lehoucq et al. (2306.09861)

Population synthesis model : COSMIC

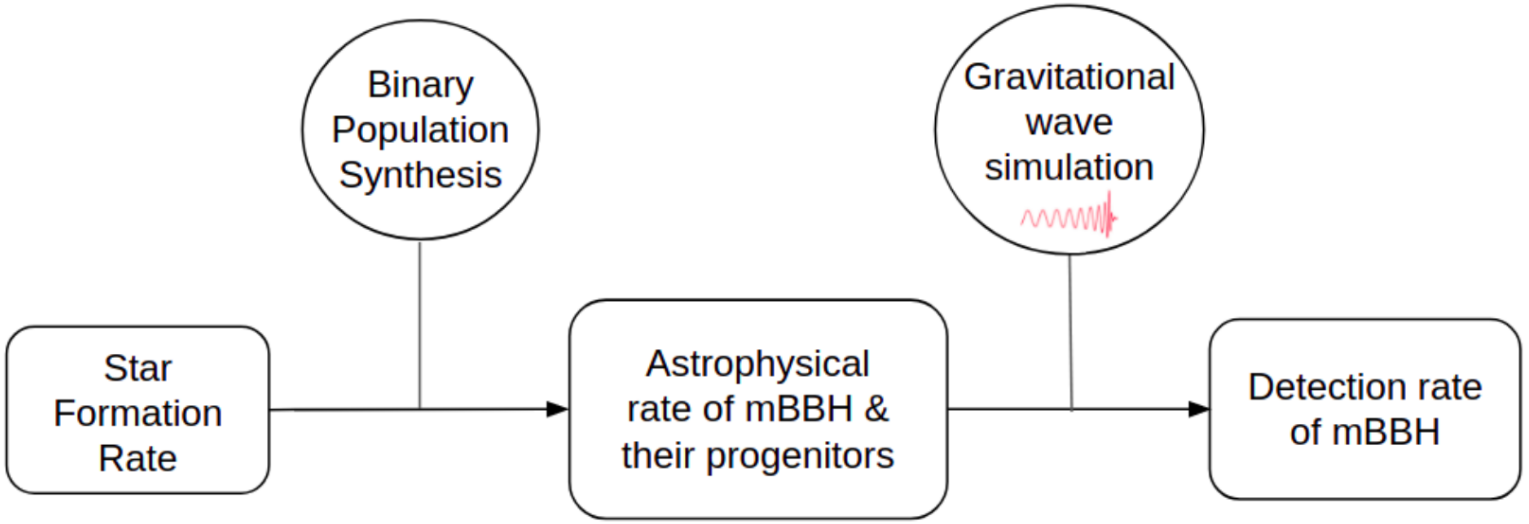
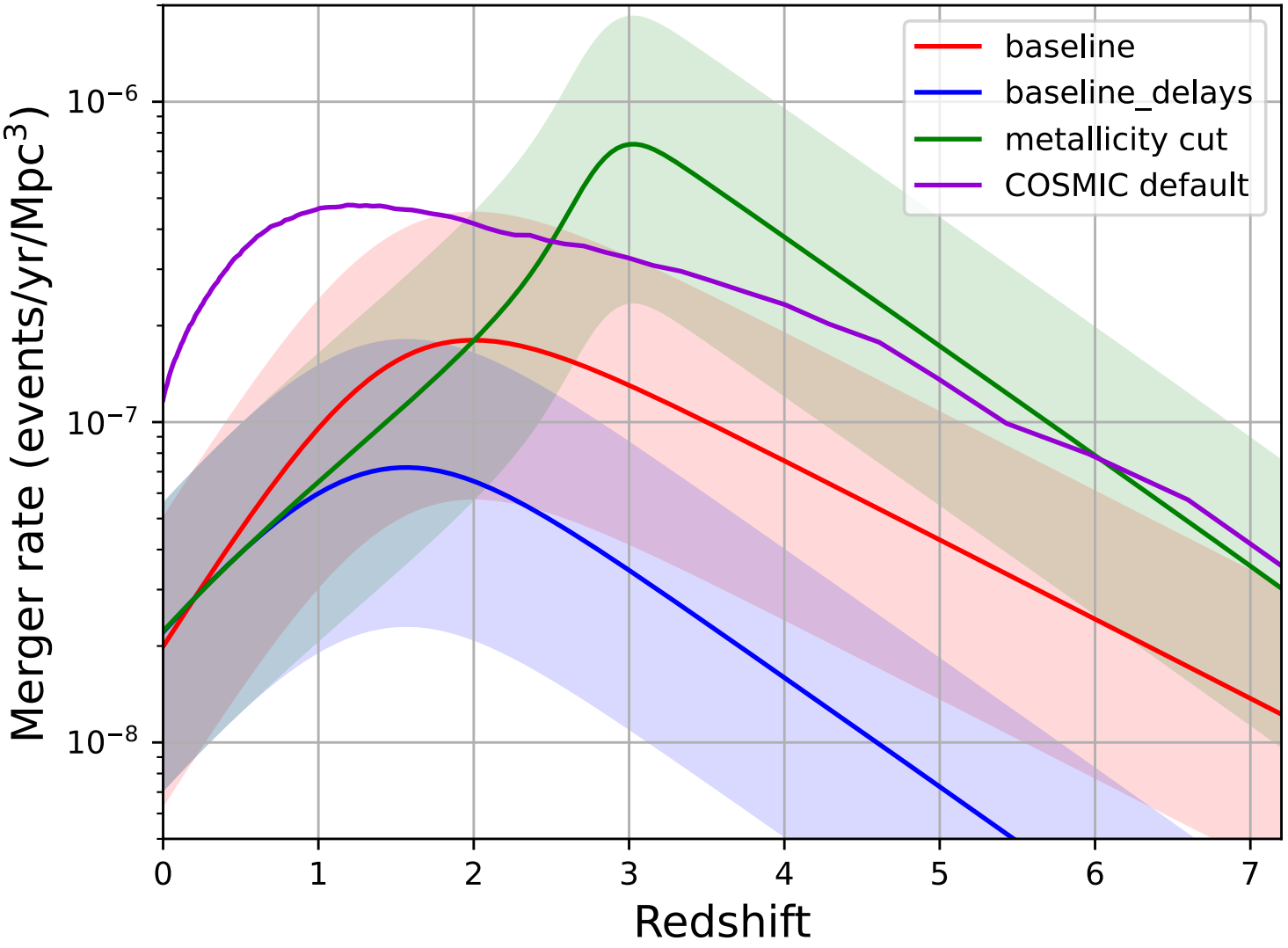


Figure from *Srinivasan et al., 2023*

- Fast and efficient to produce compact binary population
- More realistic, many physical effects taken in to account
- Many parameters difficult to constrain

Srinivasan et al., 2023, MNRAS, 524, 60 *Pellouin et al. in prep*

Merger rate of BBHs



Lehoucq et al. (2306.09861)

Stochastic GW Background

$$\Omega_{\mathrm{GW}}(f) = \frac{f}{\rho_c c^2 H_0} \int_0^{z_{\max}} \int_\lambda \frac{R_{\mathrm{merg}}(z,\lambda)\, \frac{dE_{GW}(f_s)}{df_s}\, P(\lambda)}{(1+z)\sqrt{\Omega_M (1+z)^3 + \Omega_\Lambda}}\, d\lambda\, dz$$

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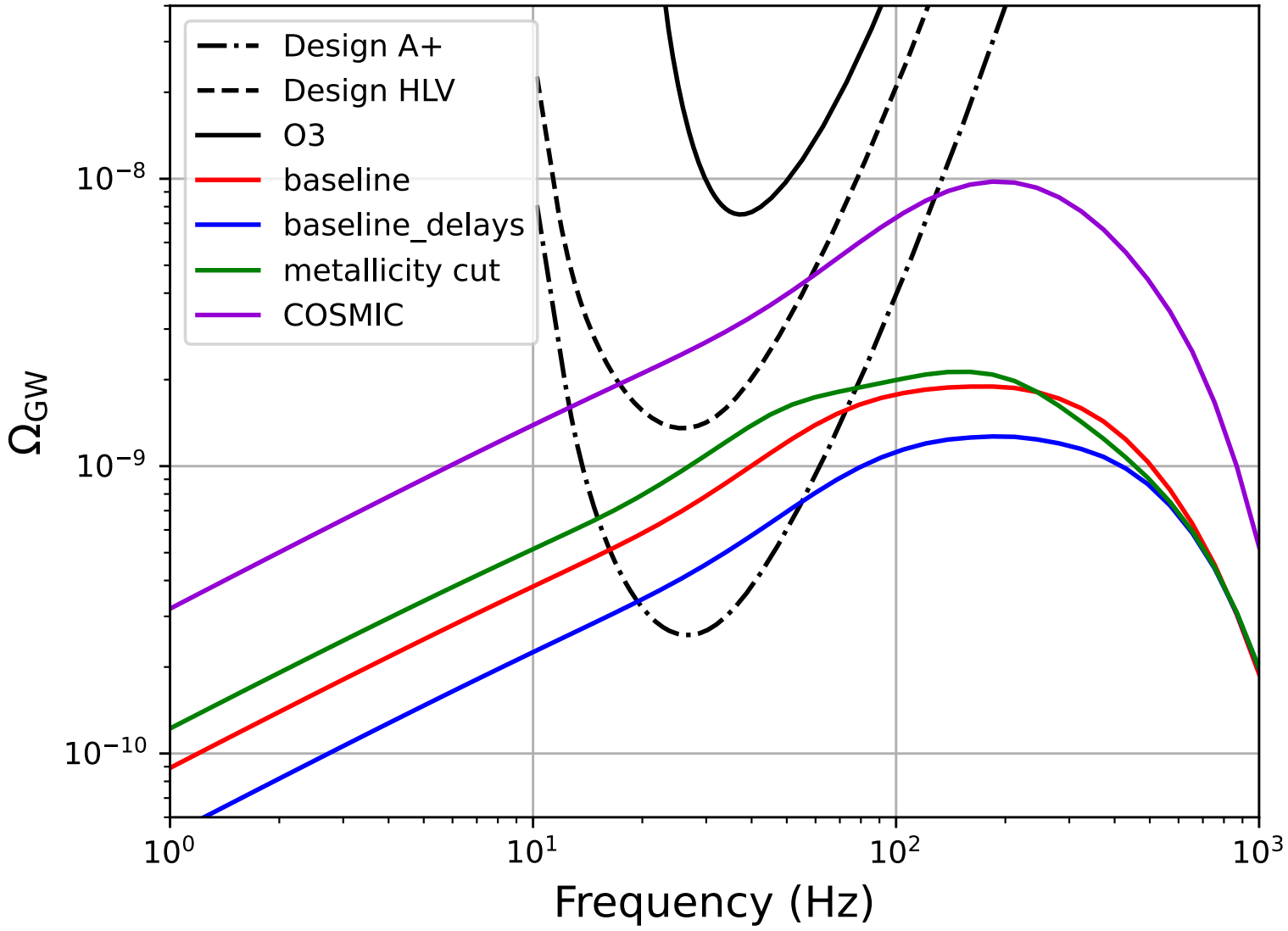
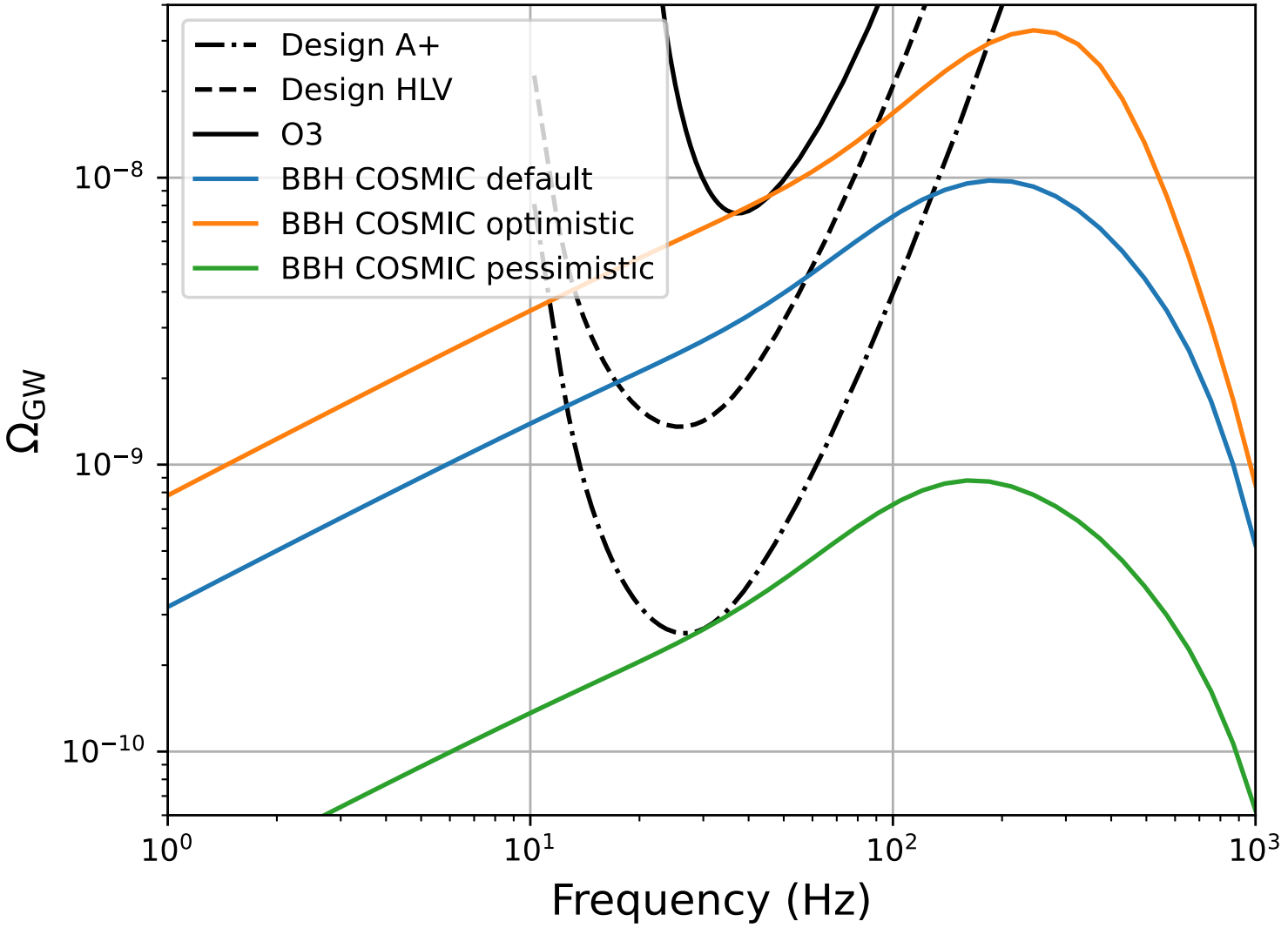
We explored the effects of the astrophysical uncertainties on the SGWB.

SGWB from BBHs



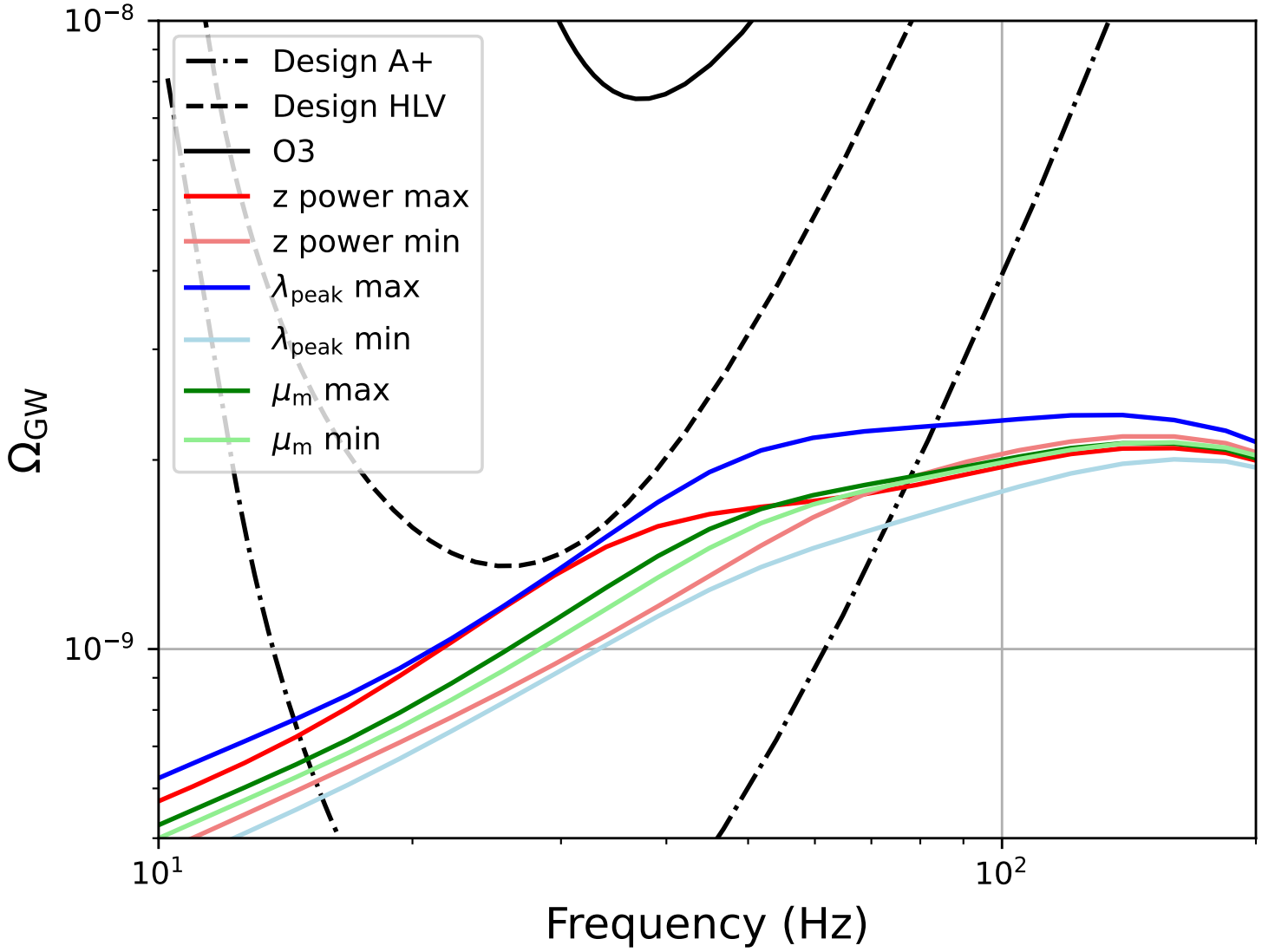
Lehoucq et al. (2306.09861)

SGWB from BBHs - pop synth models



Lehoucq et al. (2306.09861)

SGWB from BBHs - BBH mass distribution impact



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Conclusions

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- We find that some our models could be even more constrained with upcoming observations.

- A few BBHs mergers might be detectable by LISA.