Reevaluating the SGWB from BNS in an Agnostic Framework: Post-Mergers Contribution

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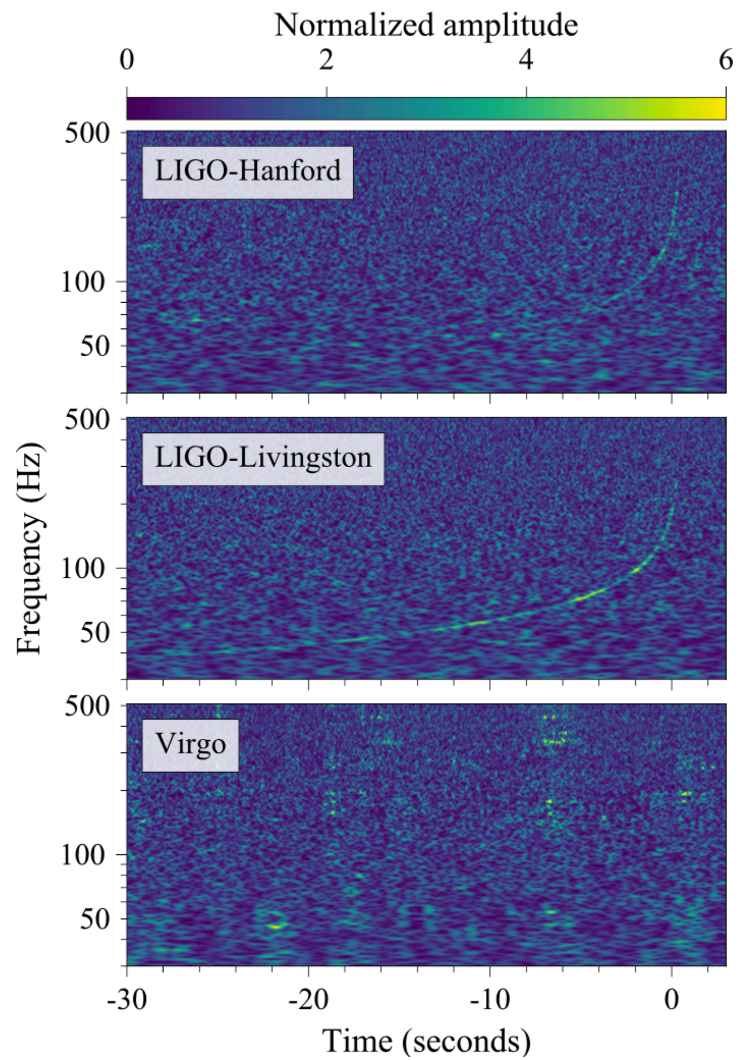
BNS mergers

- ~ 2 individual detections so far
- Amazing MMA events (GW, GRB, KN)
- But LVK sensible only up to ~500Hz, we are not looking at the full GW strain!
- What about higher frequencies > 1kHz that could be detectable with 3G detectors (ET, CE, …)?



GW170817 chirp, https://www.ligo.org

BNS merger waveform

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  - Below ~ 1kHz

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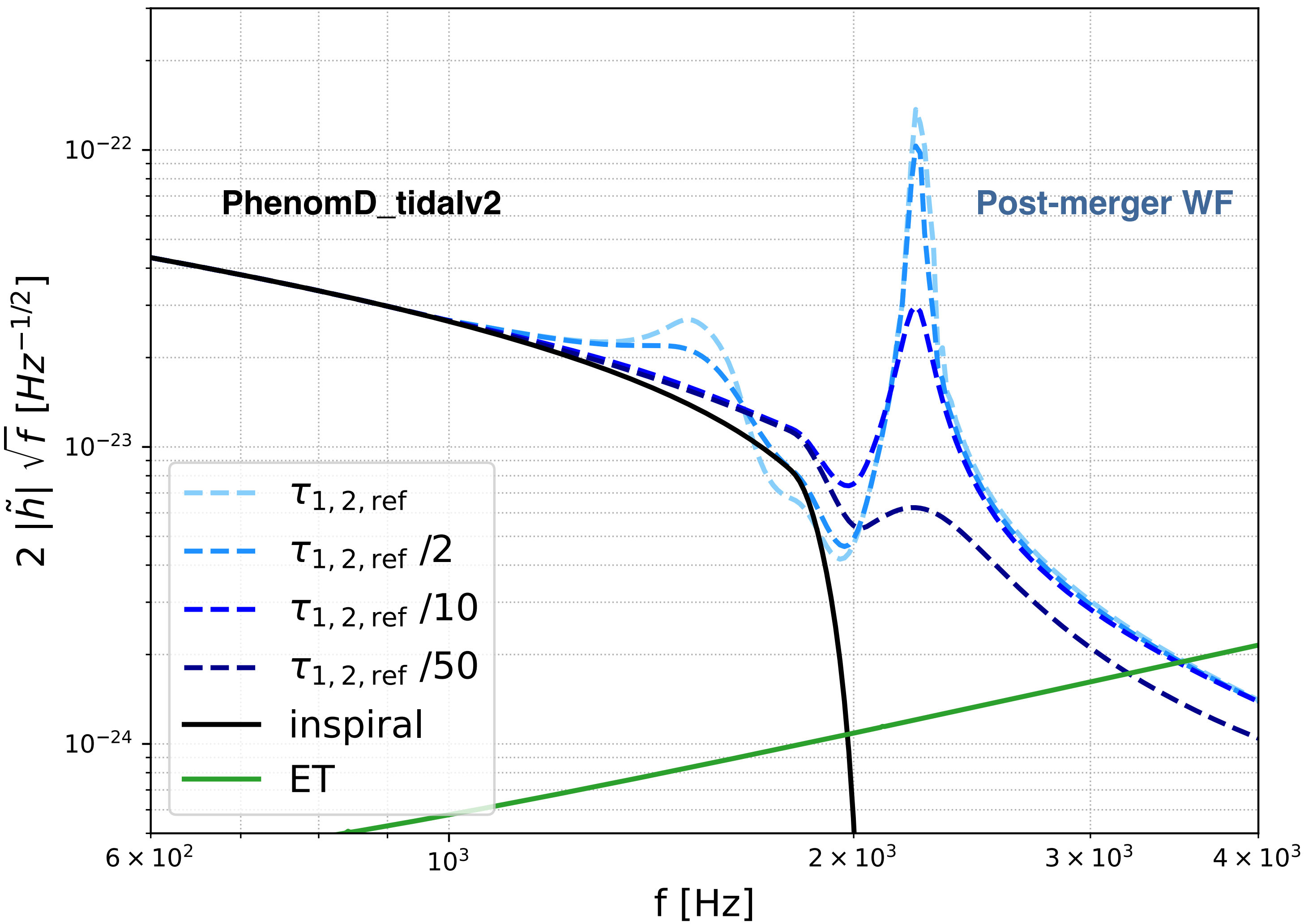
$$\begin{aligned} h_+(t) = \quad & \alpha \quad e^{-t/\tau_1} [\sin(2\pi f_1 t) + \sin(2\pi(f_1 - f_{1\epsilon})t) + \sin(2\pi(f_1 + f_{1\epsilon})t)] \\ & + \quad e^{-t/\tau_2} \sin(2\pi f_2 t + 2\pi\gamma_2 t^2 + 2\pi\xi_2 t^3 + \pi\beta_2) \qquad (1) \end{aligned}$$

Analytic WF from S.Bose, K.Chakravarti, L.Rezzolla et al. (2018)

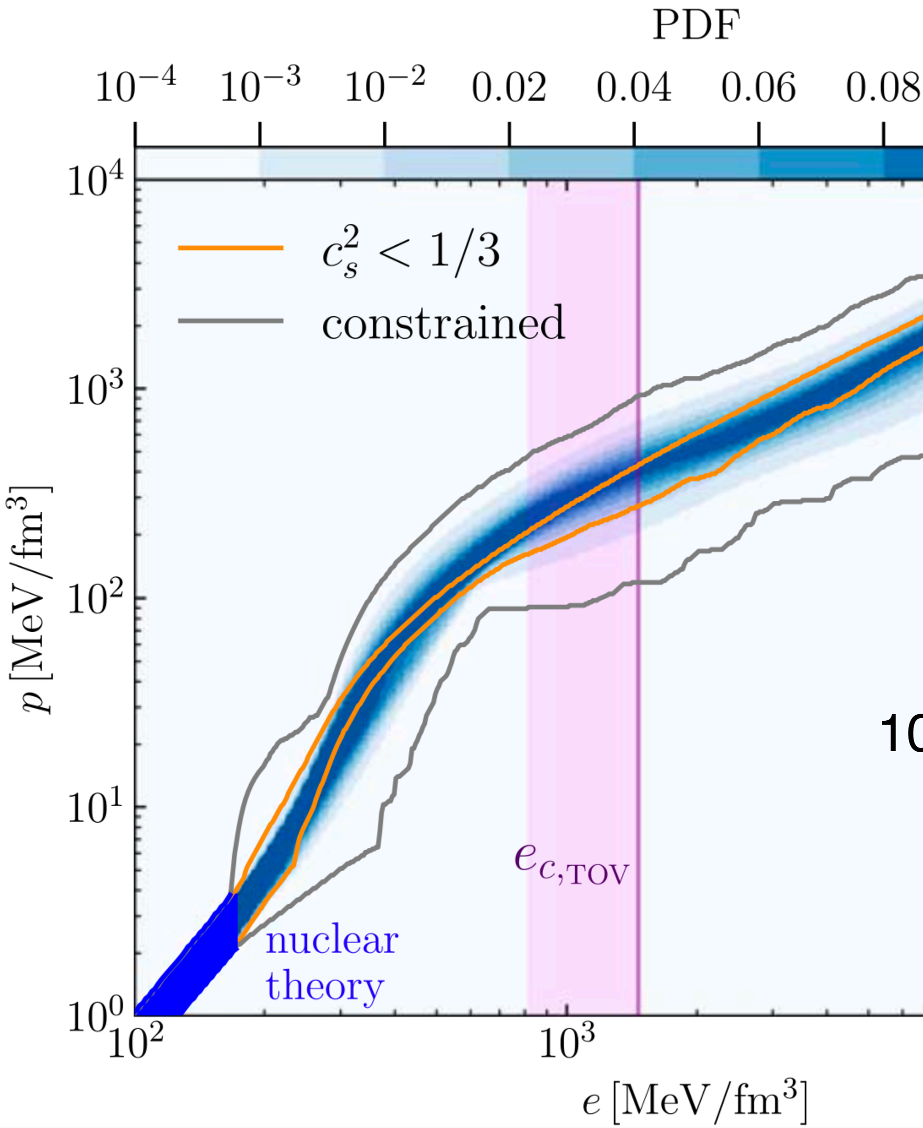
BNS merger waveform



$M_1 = M_2 = 1.250 M_\odot$, D = 50 Mpc, for the GNH3 EOS

L.Lehoucq, I.Dvorkin and L.Rezzolla in prep.

Agnostic approach of the EOS



S.Altiparmak, C.Ecker, and L.Rezzolla (2022)

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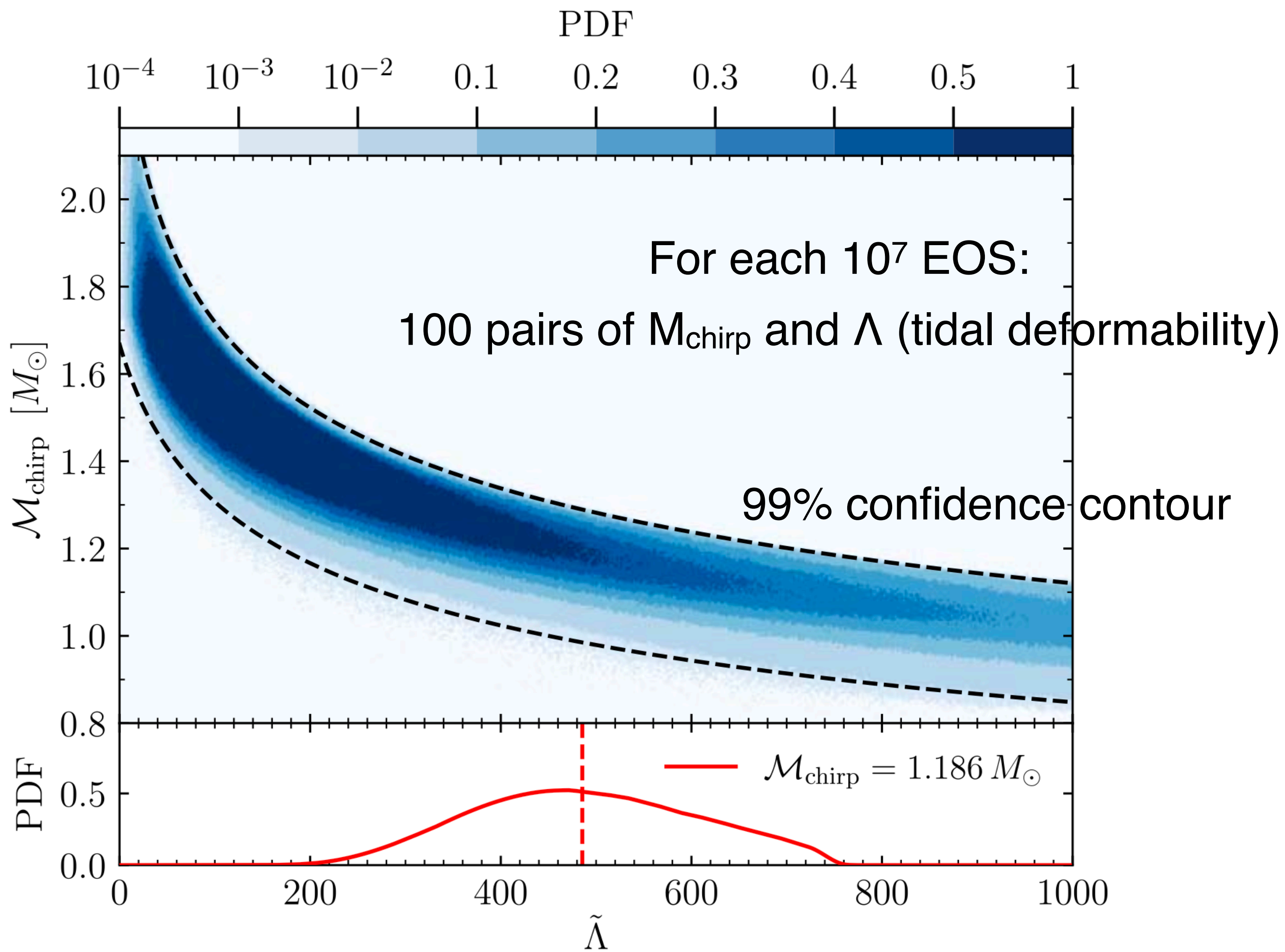

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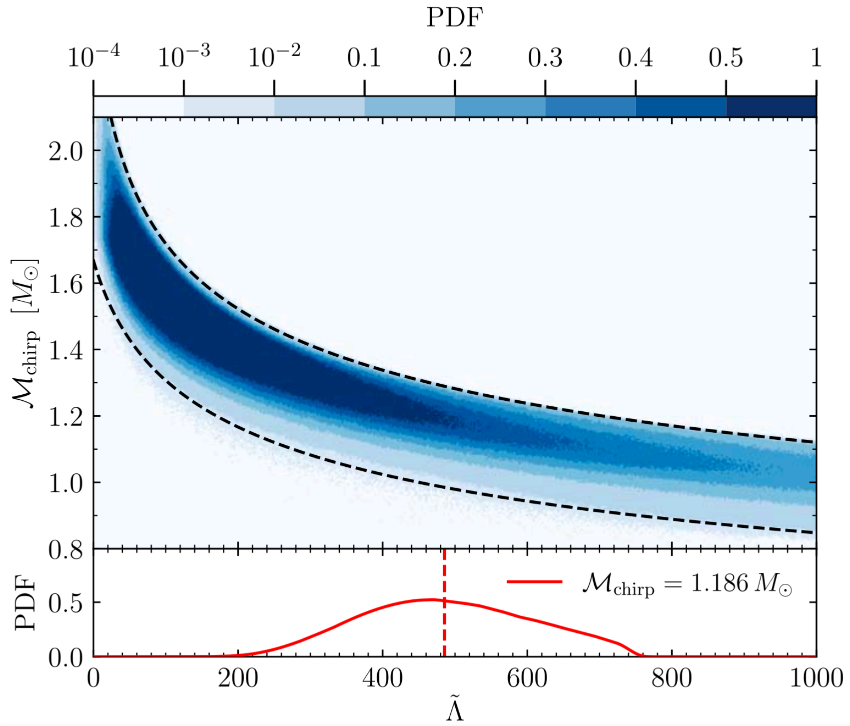
Agnostic approach of the EOS

- A priori, an EOS is not defined by a single M_{chirp}-Λ. relation

- But with only symmetric binaries, there is unicity of the relation!

- We can generate a valid EOS in accordance with the PDF, it takes the form of a power-law :



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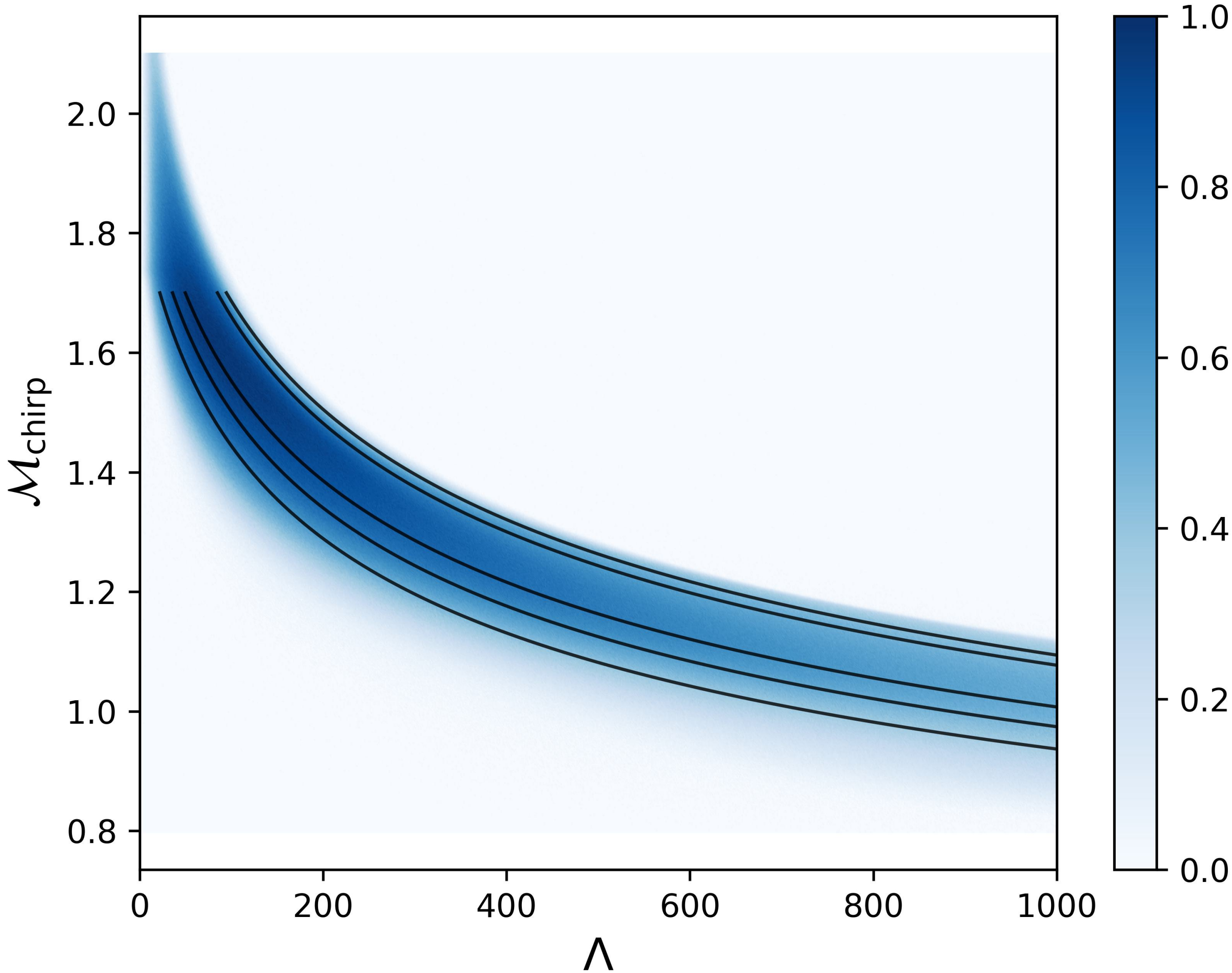
$$\Lambda = a + b\mathcal{M}_{\rm chirp}{}^{\alpha}$$

Agnostic approach of the EOS



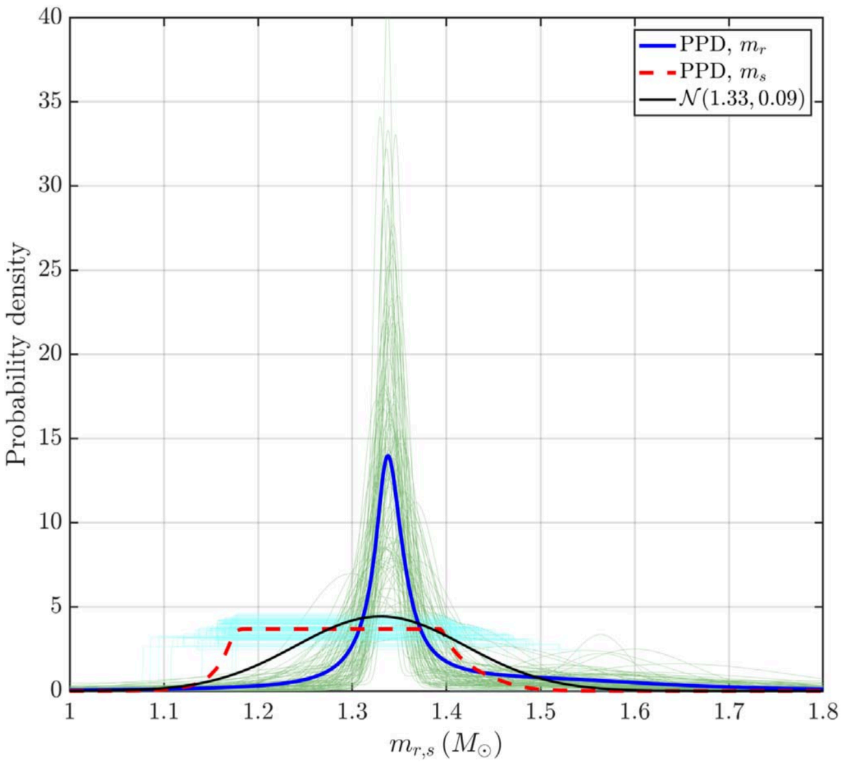
L.Lehoucq, I.Dvorkin and L.Rezzolla in prep.

BNS population modelling

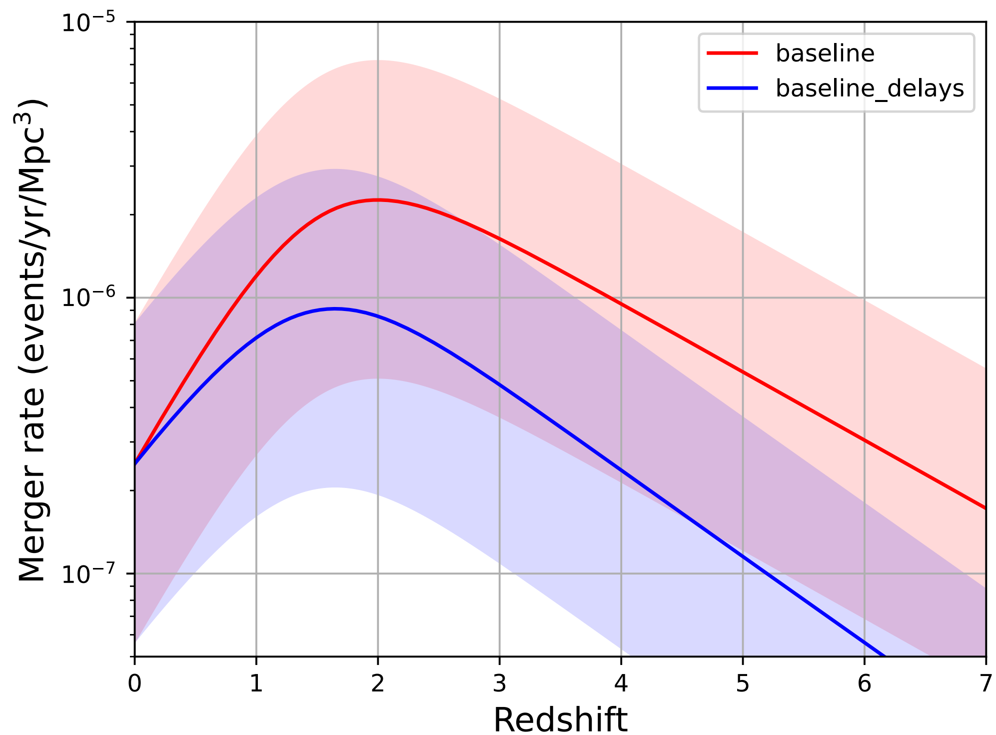
18 —> 9 BNS parameters: non-eccentric, spinless, symmetric

Parameters	BNS
m	Galactic BNS mass distribution (Farrow et al. 2019)
Λ	Calculated based on $\mathcal{M}$ and the EOS, $\Lambda = a + b\mathcal{M}_{\rm chirp}{}^{\alpha}$
z	Merger rate model *baseline_delays* (Lehoucq et al. 2023)
$\cos\iota$ $\cos\delta$	Uniform in [-1,1]
α, ψ, Φ_c	Uniform in $[0,2\pi]$
t_c	0

BNS population modelling



N.Farrow et al. 2019



L.Lehoucq et al. 2023

We take T = 1 year of observation —> N_{merger} ~ 3.8e5

Calculation of the background

Background definition:

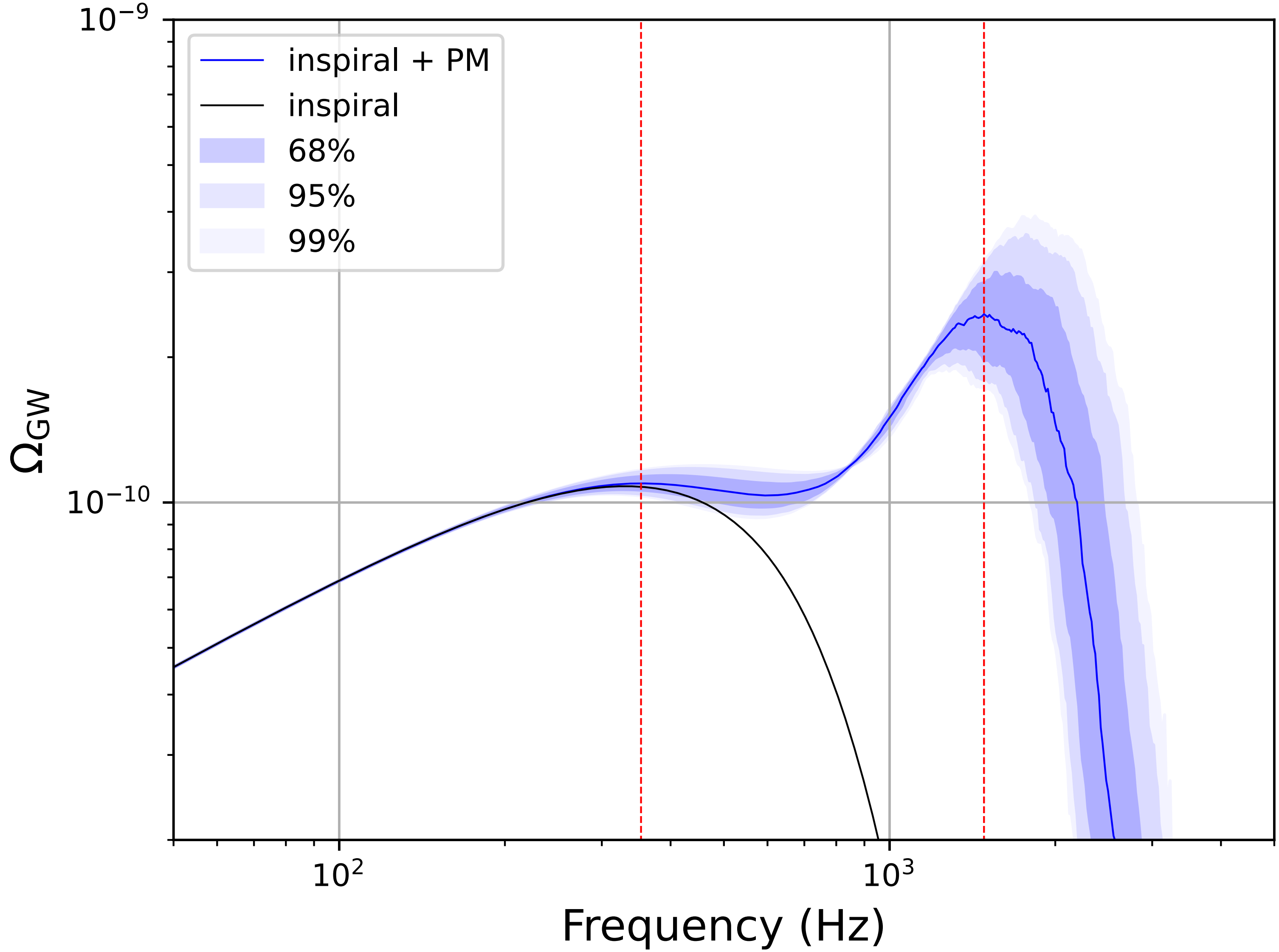
$$\Omega_{\rm GW} = \frac{1}{\rho_c}\frac{{\rm d}\rho_{\rm GW}}{{\rm d}\ln f} = \frac{f}{\rho_{\rm c} c}F(f) \quad \text{with} \quad \rho_{\rm c} = 3H_0/8\pi G$$

Total GW flux:

$$F_{\rm tot}(f) = \frac{\pi c^3}{2G}\frac{f^2}{T}\sum_{i=1}^{N}\left[|\tilde{h}_i^{+}(f)|^2 + |\tilde{h}_i^{\times}(f)|^2\right]$$

—> Sources are into 2 categories: resolved and **unresolved** (thus forming the background) based on a $\mathrm{SNR}_{\rm thr}$, usually taken to 12. Detectability using GWFish *(Dupletsa et al. 2023)*.

Results (preliminary)



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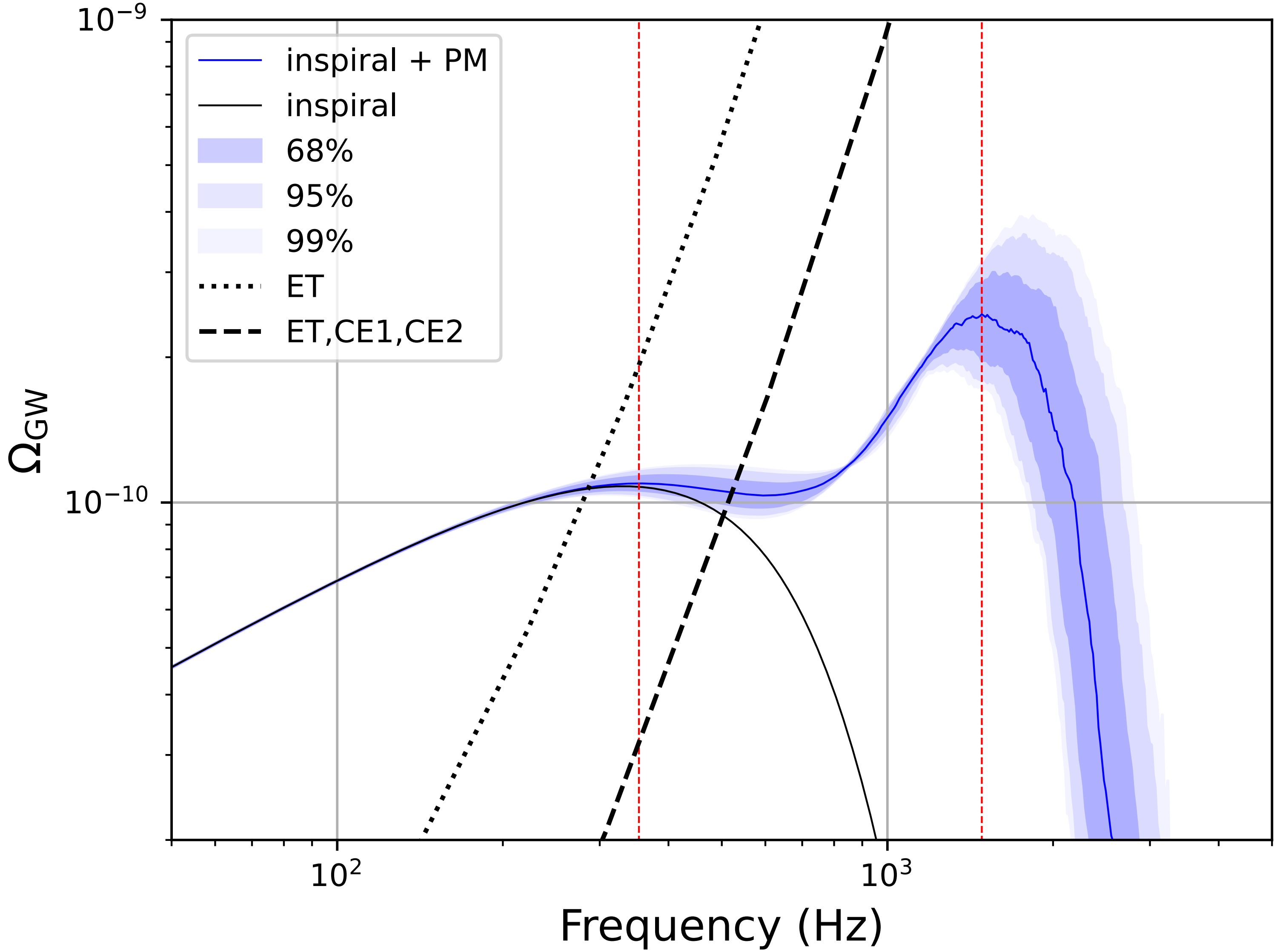

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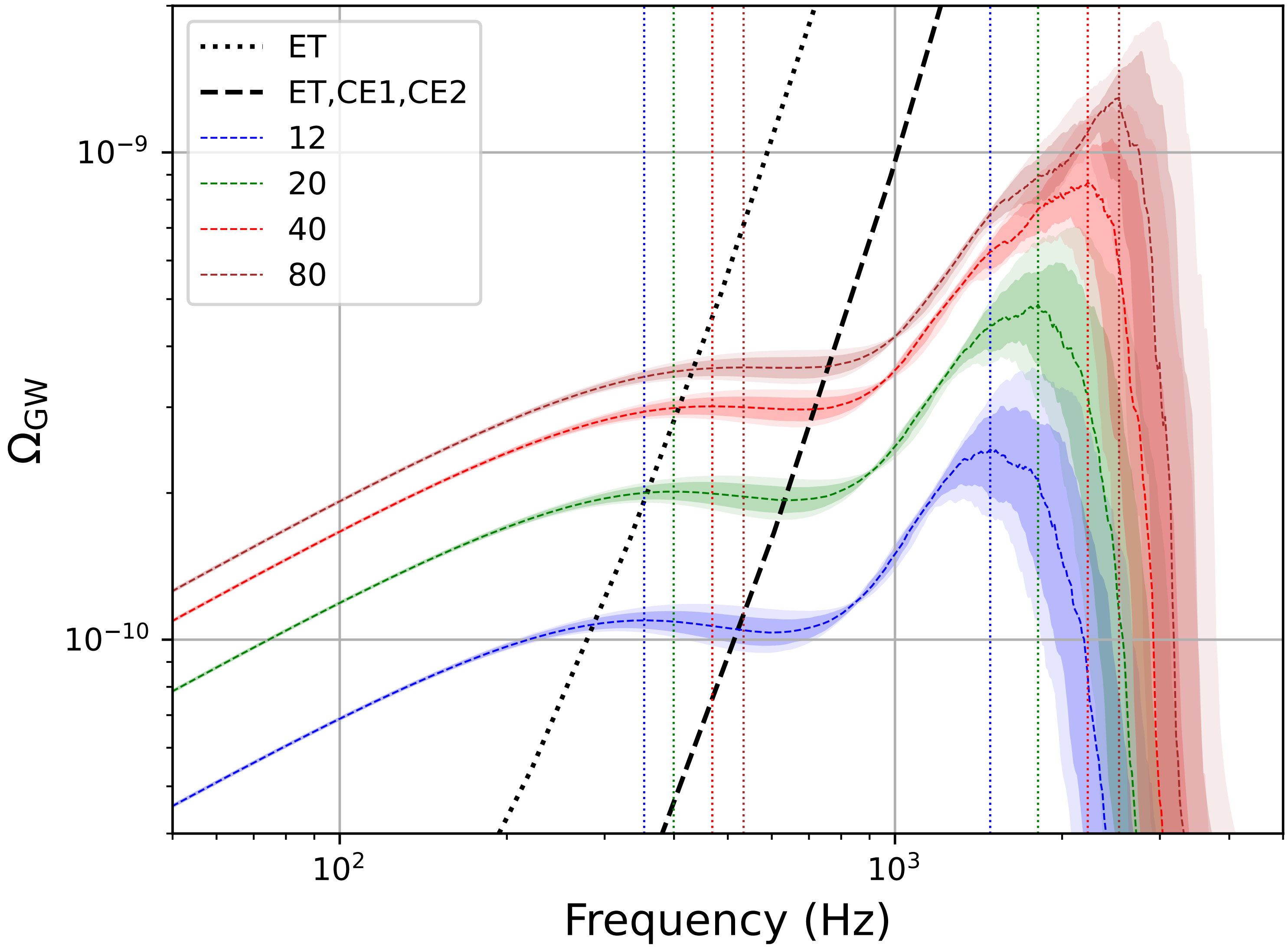

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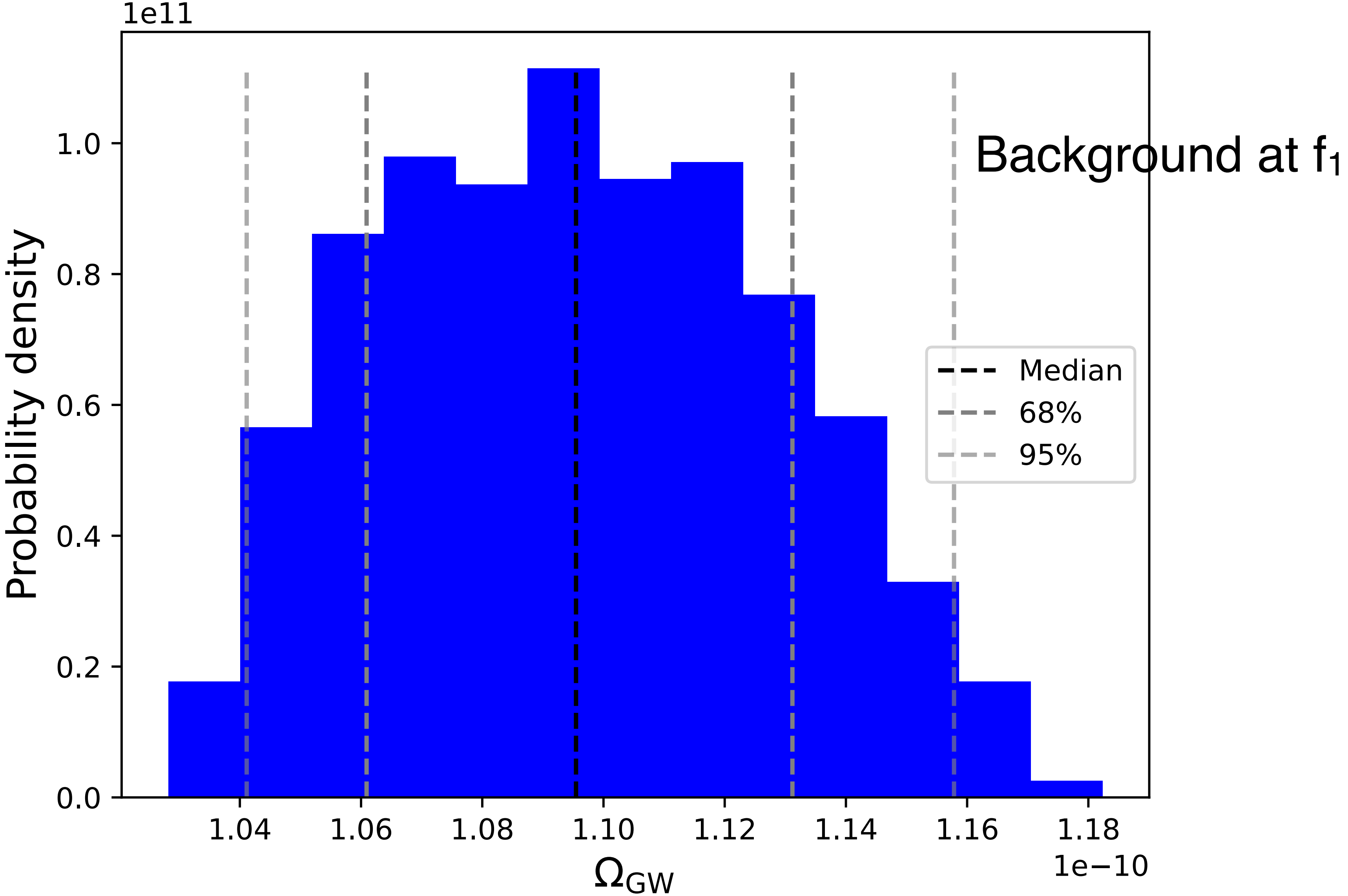

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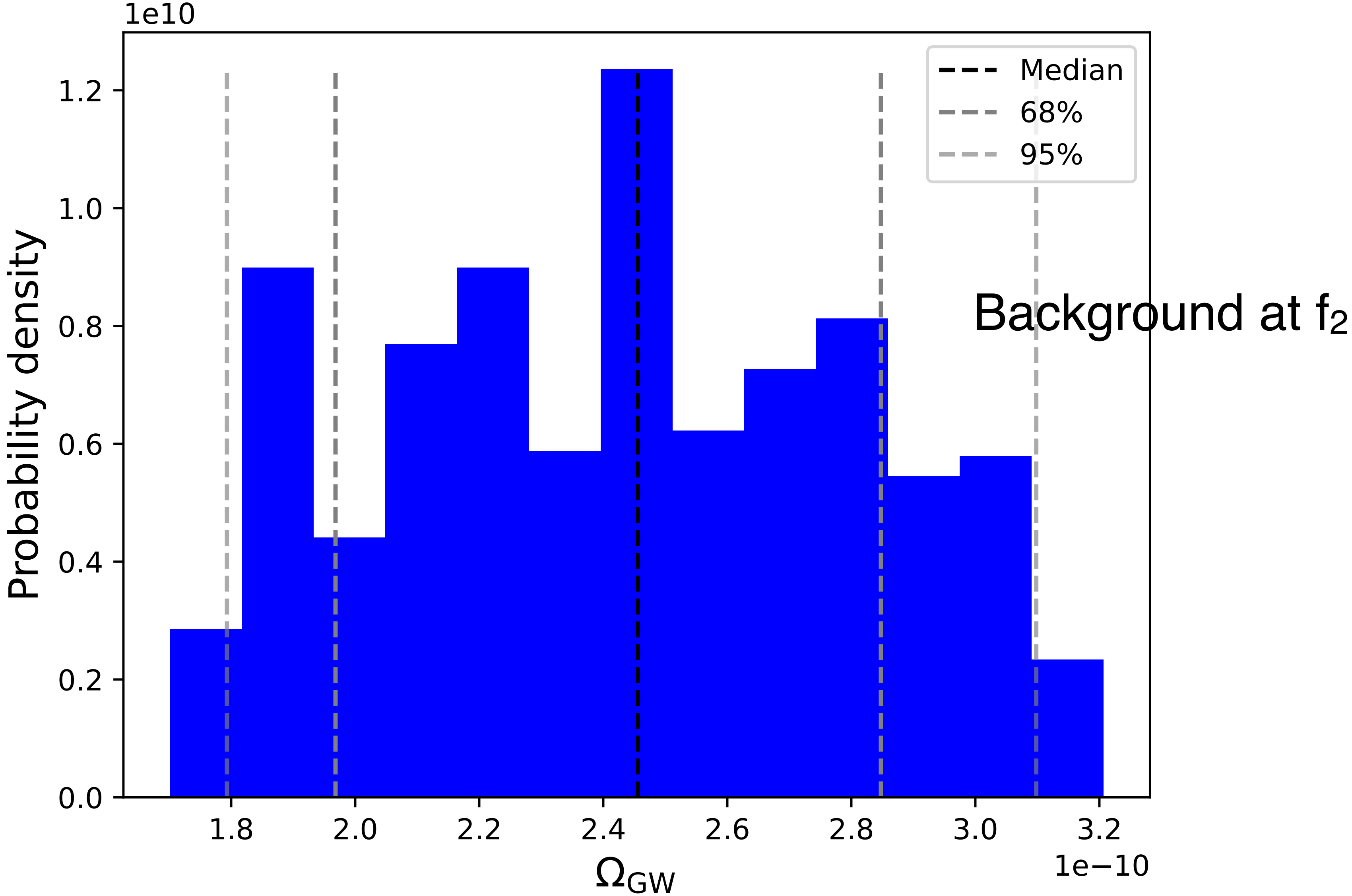

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Results (preliminary)

Lifetimes τ_1 and τ_2 are not well constrained, numerical relativity suggests:

$\tau_{1,ref} \sim$ few ms and $\tau_{2,ref} \sim 20$ ms.

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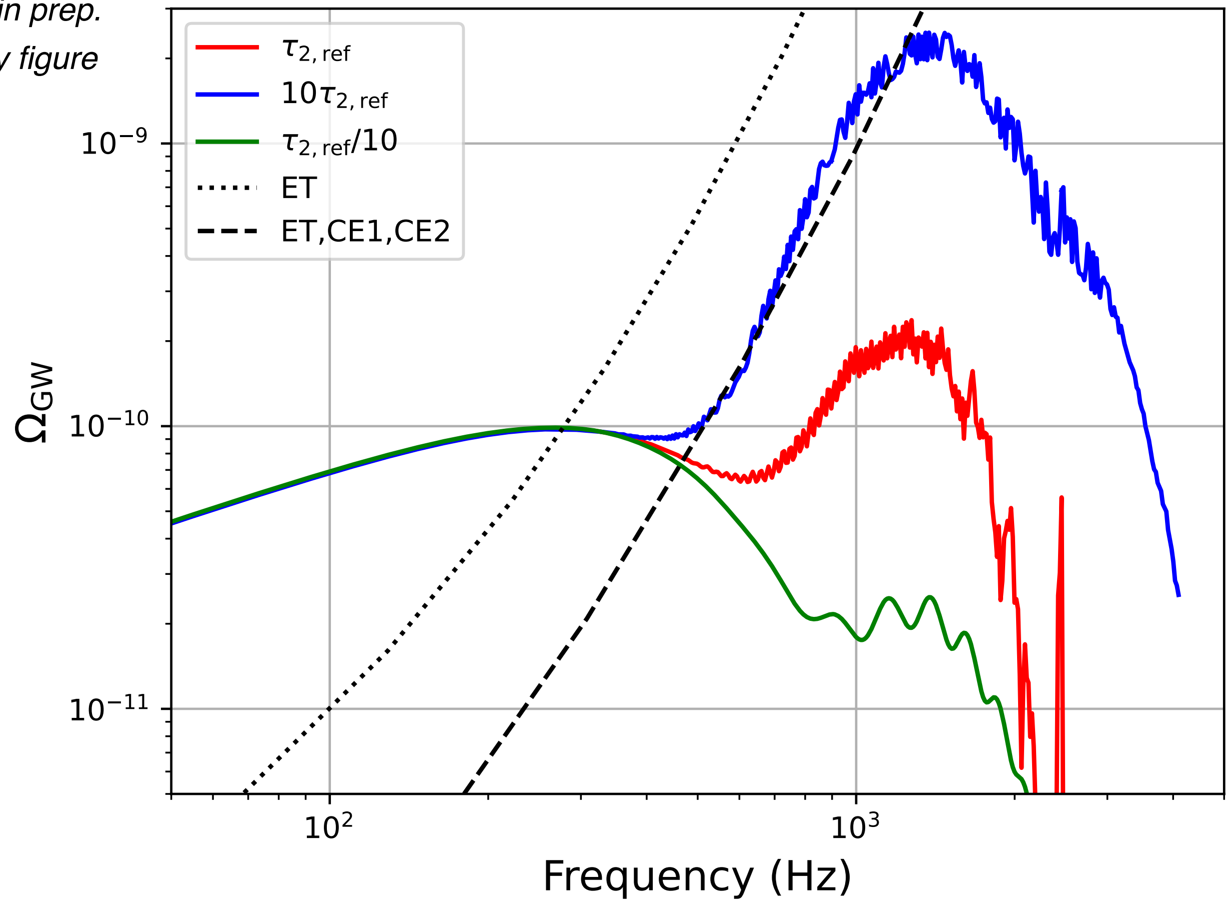
Very preliminary figure



In this example, we could set constraints up to 10 $\tau_{2,ref} \sim 200$ ms

Conclusions

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- The amplitudes of the post-merger peaks are proportional to the lifetimes of the proper modes of the HMNS.

- Unfortunately, these lifetimes are not well constrained, but 3G detectors could set interesting upper limits on them and even potentially detect the lowest frequency modes.