A “Neutrino Floor” For Gravitational Waves: The Stochastic Gravitational Wave Background from Supernova Neutrino Memory

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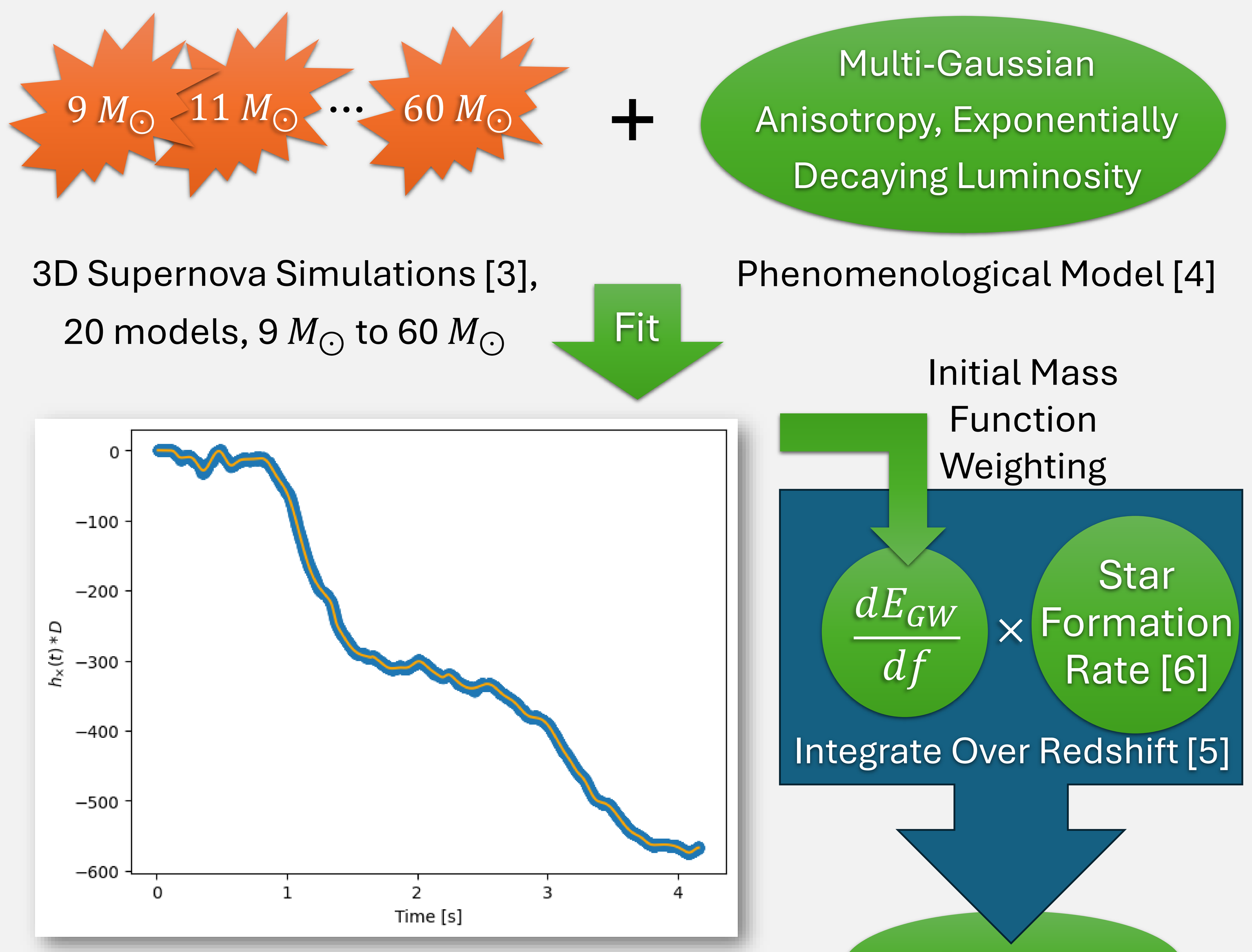
Abstract

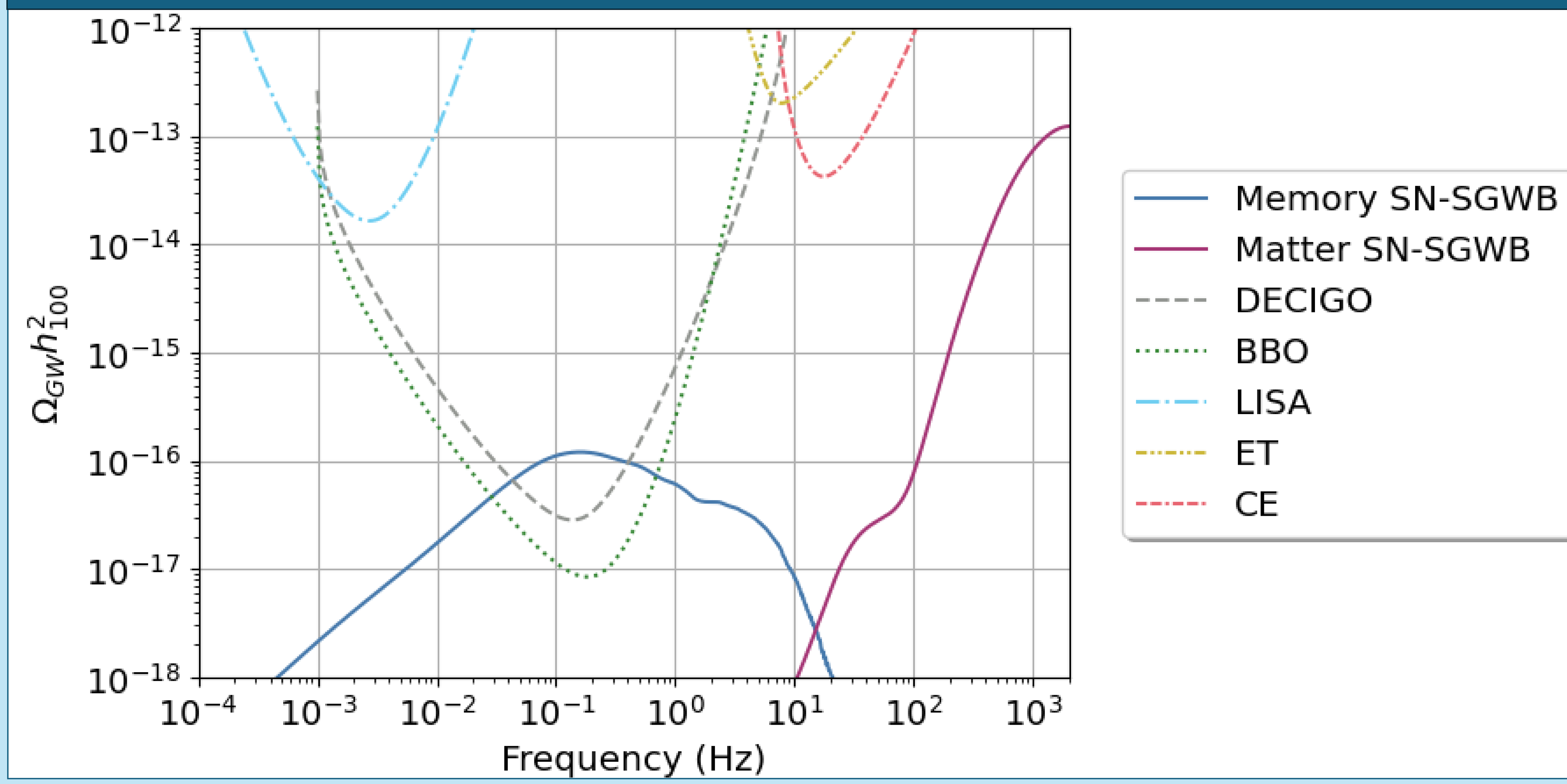
Gravitational waves originating from unresolved events, or **stochastic gravitational wave backgrounds (SGWBs)** [1], carry precious information about the physics underlying their varied sources. Here, we predict the **SGWB due to low-frequency gravitational waves originating from anisotropic emission of neutrinos during supernovae** – also known gravitational wave memory [2] – over a range of frequencies. Built using **state-of-the-art 3D simulations** capturing the first several seconds of a supernova [3], our phenomenological model [4] accounts for both early-time spiral SASI effects as well as long-term memory effects, and accounts for mass differences in the stellar population. When compared to the SGWB from proto-neutron star oscillations, we note the emergence of a **distinct feature in the spectrum** that (1) may be **detectable with futuristic space-borne detectors** and (2) may itself **act as a background for cosmological SGWB searches**.

Our Model



Fits Performed for All Progenitor Masses

Results



Long-term memory effects

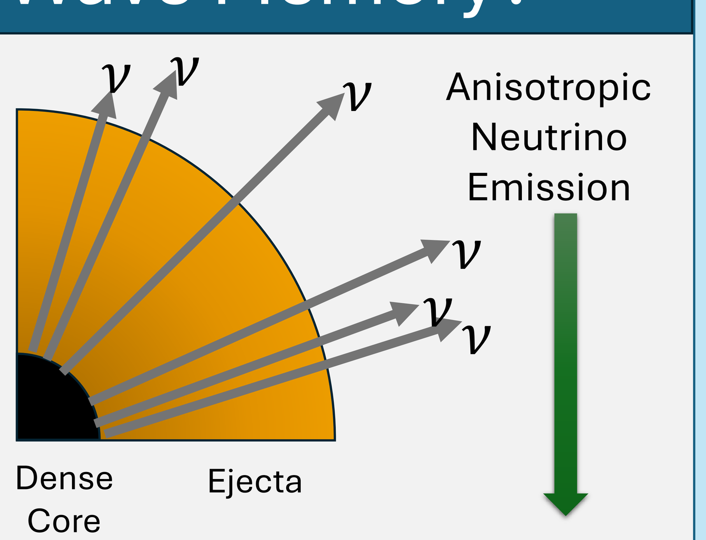
Deci-Hertz peak in the gravitational wave spectrum

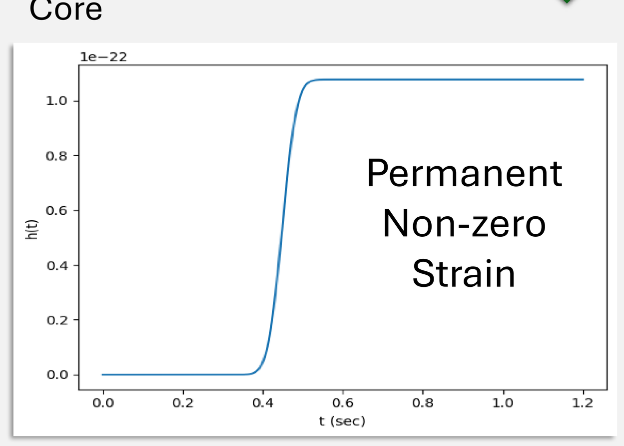
Waveforms from simulations of varying progenitor masses, weighted by the initial mass function

Shape and overall amplitude of the spectrum

What is Gravitational Wave Memory?

- Core-collapse supernovae release up to ~99% of their gravitational binding energy as neutrinos.
- This emission is not perfectly isotropic.
- Anisotropic neutrino emission sources low-frequency gravitational waves.
- This causes a permanent deformation of the metric – the “memory” effect [2].





Conclusions

- Accurate predictions require **modeling the memory waveforms for several seconds and for different types of progenitors**
- The supernova neutrino memory SGWB may **act as a background** for other searches in the deci-Hertz frequency band, analogous to the “neutrino fog” found in dark matter direct detection experiments.
- The SGWB signal from supernova neutrino memory **may be detectable** with future space-based detectors

Acknowledgements

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References

[1] A. Renzini, B. Goncharov, A. C. Jenkins, P. M. Meyers, Galaxies 10, 1 (2022), 10.3390/galaxies10010034, [arXiv:2202.00178 [gr-qc]]

[2] R. Epstein, Astrophys. J. 223 (1978), 10.1086/156337

[3] L. Choi, A. Burrows, D. Vartanyan, Astrophys. J. 975, 1 (2024), 10.3847/1538-4357/ad74f8, [arXiv:2408.01525 [astro-ph.HE]]

[4] M. Mukhopadhyay, C. Cardona, C. Lunardini, JCAP 07 (2021), 10.1088/1475-7516/2021/07/055, [arXiv:2105.05862 [astro-ph.HE]]

[5] E. S. Phinney, (2001), 10.48550/arXiv.astro-ph/0108028, [arXiv:0108028 [astro-ph]]

[6] K. Crocker, T. Prestegard, V. Mandic, T. Regimbau, K. Olive, E. Vangioni, Phys. Rev. D 95, 6 (2017), 10.1103/PhysRevD.95.063015, [arXiv:1701.02638 [astro-ph.CO]]