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Non-Parametric Normalizing Flow Modeling of Binary Black Hole Populations for Unbiased Dark Siren Cosmology

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Gravitational-wave (GW) dark siren methods offer a powerful way to measure the expansion of the Universe without electromagnetic counterparts, but they rely critically on accurate models of the underlying binary black-hole (BBH) population. In fact, conventional parametric descriptions of BBH mass and redshift distributions can lead to significant biases in cosmological inferences when the assumed functional forms are incorrect. We present a fully non-parametric approach using Normalizing Flows (NFs) to model the joint BBH source-frame mass and redshift distribution within a hierarchical Bayesian framework. Training on simulated GW catalogs representative of current observing runs (~10^2–10^3 events), we optimize the NF parameters by maximizing the hierarchical likelihood, demonstrating flexible recovery of complex, multimodal features without manual tuning of functional forms. This non-parametric population model might mitigate biases in dark siren cosmology arising from oversimplified population assumptions. Future work will extend this framework to full posterior sampling of the NF parameters and application to real GW data.

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