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Inferring host galaxy probablities with a systematics-free approach in dark siren cosmology

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The rapidly growing field of dark siren cosmology, driven by advances in gravitational wave detection campaigns and galaxy surveys, is progressing towards independent and increasingly precise measurements of the Hubble constant.
As statistical uncertainties shrink, it becomes crucial to address and eliminate potential dominant systematics. A key source of bias, investigated in previous studies, arises from the currently unknown probability that a merger occurs in a given host galaxy as a function of its physical properties such as its absolute luminosity raised to some power, referred to as *galaxy weight*.
In this presentation, we show that galaxy weights can be treated as population-level hyperparameters and jointly inferred from data, rather than fixed *a priori*, with a consistent and rigorous population-based weighting scheme for compact-binary host galaxies. We perform the inference in the high dimensional parameter space ($>> 100$) that also includes single-event and cosmological parameters, e.g. the Hubble constant. On one hand, this approach allows us to consistently estimate the host probabilities for each event, thereby identifying the most likely host galaxies and potentially uncovering links between their astrophysical properties and those of the hosted events. On the other hand, by exploiting Hamiltonian Monte Carlo algorithms, we are able to sample the full hierarchical population posterior and investigate correlations across parameters at all levels. At the same time, we avoid sources of numerical systematics associated with multi-dimensional Monte Carlo integrals in the likelihood, which could soon become a limiting factor for current analysis pipelines.

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