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Reconstructing the Origin of Black Hole Mergers Using Sparse Astrophysical Models

Abstract

The astrophysical origin of binary black hole mergers discovered by LIGO and Virgo remains uncertain. Efforts to reconstruct the processes that lead to mergers typically rely on either astrophysical models with fixed parameters, or continuous analytical models that can be fit to observations. Given the complexity of astrophysical formation mechanisms, these methods typically cannot fully take into account model uncertainties, nor can they fully capture the underlying processes. Here, we present a merger population analysis that can take a discrete set of simulated model distributions as its input to interpret observations. The analysis can take into account multiple formation scenarios as fractional contributors to the total set of observations, and can naturally account for model uncertainties. We apply this technique to investigate the origin of black hole mergers observed by LIGO–Virgo. Specifically, we consider a model of AGN-assisted black hole merger distributions, exploring a range of AGN parameters along with several SEVN population synthesis models that vary in common envelope efficiency parameter (α) and metallicity (Z). We estimate the posterior distributions for AGN+SEVN models using 87 BBH detections from the O1 − −O3 observation runs. The inferred total merger rate is 46.2 Gpc−3yr−1, with the AGN sub-population contributing 21.2 Gpc−3yr−1 and the SEVN sub-population contributing 25.0 Gpc−3yr−1.