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Constraining Cosmology with Next-Generation Gravitational Wave Detectors

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Next-generation gravitational wave (GW) detectors are expected to detect hundreds of thousands of events per year. This will provide a rich dataset to not only study the binary black hole (BBH) source population but also test cosmological models. Each GW event offers a direct estimate of the luminosity distance to the source. When coupled with the redshift, this enables the construction of a redshift–distance relation to infer the Hubble constant, H_0. We begin by simulating a catalog of luminosity distances and BBH masses. Through the "spectral sirens"method, we exploit intrinsic features in the BBH mass function to infer the redshift to the source. We examine how factors such as peak evolution, measurement errors in mass and distance, and the number of detected events influence the resulting H0 posterior. We demonstrate that with a sufficiently large sample of detections and realistic observational uncertainties, this approach can achieve percent-level precision on H_0. Furthermore, we show that it is possible to decouple the evolution of the BBH source population from the inferred cosmological parameters. These results highlight the promise of spectral sirens as a complementary cosmological probe in upcoming gravitational-wave surveys.

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