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Comparing gravitational waveform models for binary black hole mergers through a hypermodels approach

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The inference of source parameters from gravitational-wave signals relies on theoretical models that describe the emitted waveform. Different model assumptions on which the computation of these models is based could lead to biases in the analysis of gravitational-wave data. In this work, we sample directly on four state-of-the-art binary black hole waveform models from different families, in order to investigate these systematic biases from the 13 heaviest gravitational-wave sources with moderate to high signal-to-noise ratios in the third Gravitational-Wave Transient Catalog (GWTC-3). All models include spin-precession as well as higher-order modes. Using the "hypermodels"technique, we treat the waveform models as one of the sampled parameters, therefore directly getting the odds ratio of one waveform model over another from a single parameter estimation run. From the joint odds ratio over all 13 sources, we find the model NRSur7dq4 to be favored over SEOBNRv4PHM, with an odds ratio of 29.43; IMRPhenomXPHM and IMRPhenomTPHM have an odds ratio, respectively, of 4.70 and 5.09 over SEOBNRv4PHM. However, this result is mainly determined by three events that show a strong preference for some of the models and that are all affected by possible data quality issues. If we do not consider these potentially problematic events, the odds ratio do not exhibit a significant preference for any of the models, and, overall, we do not find one model to be consistently preferred over the others. This is unexpected, considering that we included NRSur7dq4 in the analysis, which is predicted to be the most accurate model for high-mass signals, being interpolated from NR simulations. Nonetheless, we systematically find that the models recovering evidence of precession are the ones with the higher probabilities. Although further work studying a larger set of signals will be needed for robust quantitative results, the presented method highlights one possible avenue for future waveform model development.

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