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Modeling matter(s) in SEOBNRv5THM: Generating fast and accurate effective-one-body waveforms for spin-aligned binary neutron stars

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We present SEOBNRv5THM, an accurate and fast gravitational-waveform model for quasi-circular, spinning, non-precessing binary neutron stars (BNS) within the effective-one-body (EOB) formalism. It builds on the binary-black-hole approximant SEOBNRv5HM and, compared to its predecessor SEOBNRv4T, it i) incorporates recent high-order post-Newtonian results in the inspiral, including higher-order adiabatic tidal contributions, spin-induced multipoles and dynamical tides for spin-aligned neutron stars, ii) includes the gravitational modes $(\ell, |m|) = (2,2), (3,3), (2,1), (4,4), (5,5), (3,2)$, and $(4,3)$, iii) has a time of merger calibrated to BNS numerical-relativity (NR) simulations, iv) accurately models the pre-merger $(2,2)$ mode through a novel phenomenological ansatz, and v) is 100 to 1000 times faster than its predecessor model for BNS systems with total mass $M \geq 2\,M_{\odot}$. Thus, SEOBNRv5THM can be used in Bayesian parameter estimation, which we perform for two BNS events observed by the LIGO-Virgo Collaboration, GW170817 and GW190425. The model accurately reproduces BAM and SACRA NR waveforms with errors comparable to or lower than the intrinsic NR uncertainty. We validate the model against the other state-of-the-art BNS waveform models NRTidalv3 and TEOBResumS and find differences only for highly spinning and highly tidally deformable BNS, where there is no NR coverage and the models employ different spin prescriptions. Our model serves as a foundation for the development of subsequent SEOBNR waveform models with matter that incorporate further effects, such as spin-precession and eccentricity, to be employed for upcoming observing runs of the LIGO-Virgo-KAGRA Collaboration and future facilities like the Einstein Telescope.

Author: HABERLAND, Marcus (Max Planck Institute for Gravitational Physics (Albert Einstein Institute))

Presenter: HABERLAND, Marcus (Max Planck Institute for Gravitational Physics (Albert Einstein Institute))

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