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Measuring the neutron-star equation of state from gravitational-wave observations of coalescing compact binaries

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Gravitational-wave observations of inspiralling binary neutron star (BNS) and black hole–neutron star (BHNS) systems can be used to measure the unknown neutron-star equation of state (EOS). The most reliable information is likely to come from tidal interactions that increase the rate of inspiral and lead to a phase shift in the waveform. The strength of tidal interactions is parameterized by the tidal deformability Λ which is a function of the EOS and NS mass. The magnitude of the effect strongly depends on the mass ratio, so BNS systems, with nearly equal NS masses, are expected to provide the dominant source of information during the inspiral. Recent work has shown that when second generation detectors, now being commissioned, reach design sensitivity, they will be able to measure Λ with statistical errors of $\mathcal{O}(50\%)$. Furthermore, stacking observations from several BNS inspiral events dramatically decreases the statistical errors, and, for realistic event rates, it may possible to measure the NS tidal deformability to $\mathcal{O}(10\%)$ from a year of observations. These tidal deformability measurements can also be combined with other constraints such as causality and high-mass observations to directly measure the EOS with statistical errors in the pressure of less than a factor of two. Current uncertainties in the post-Newtonian waveform model, however, lead to systematic errors in the EOS measurement that are as large as the statistical errors, and more accurate waveform models are needed to minimize this error. The merger dynamics of BNS and BHNS systems depend more strongly on the EOS than for the inspiral dynamics, and can potentially provide additional EOS information. However, the merger occurs at higher frequencies where gravitational-wave detectors are less sensitive. For BHNS systems, we found, using a large set of numerical simulations, that Λ is also the best measured parameter during the merger and ringdown. With these simulations, we calibrated a phenomenological inspiral-merger-ringdown waveform model and found that matter effects can only be detected by second generation detectors for nearby systems with small BH masses and large BH spins. Third generation detectors such as the proposed Einstein Telescope, however, may be able to measure matter effects for more realistic BHNS systems. For BNS mergers, significant effort has gone into improving the accuracy of numerical simulations and understanding how the waveform depends on the EOS, but comparatively few works have examined the measurability of the EOS with gravitational-wave detectors. I will briefly review recent progress, and discuss future data-analysis work needed to reliably extract EOS information from the merger of BNS systems.