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Effects of Phase Transition in Gravitational Wave Signals From Binary Neutron Star Mergers

Quantum chromodynamics predicts that at high enough temperature/density, hadronic matter (HM) deconfines to quark-gluon matter. it is conjectured that the deconfinement transition from HM to quark matter (QM) takes place at an intermediate density range (a few times nuclear matter density). However, there is no ab-initio calculation, nor are there any earth-based experiments. The only naturally present laboratories to probe matter at such densities are the neutron stars (NSs).
We performed the full-3D GRMHD simulations of binary NS merger systems and studied the effects of the onset of phase transition (PT) by probing the stellar properties and gravitational wave spectra. We used the hybrid equation of state (EoS), which has the hadronic degrees of freedom at low density, the mixed-phase region at intermediate density, and pure QM at very high density. We constructed different hybrid EoSs by varying the onset point where quark matter first appears and performed various BNSMs (equal and unequal mass binaries).
A significant difference is observed in the post-merger properties if QM appears at low densities. If the matter properties with hadronic and quark degrees differ significantly, it is reflected in the stability of the final merger product. Hadronic EoS can give a stable post-merger remnant, whereas in hybrid EoS cases, the possibility of a core-collapse scenario increases. However, when unequal mass binaries (the mass difference is significant) merge, the difference in the observational signals depending on the EoS is evident from the point of first contact between the stars.

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