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Impact of pions on binary neutron star mergers

We investigate the impact of pions on simulations of neutron star mergers and explore their effects on gravitational-wave observables. We model both charged and neutral pions as a non-interacting Boson gas with chosen values of constant effective mass. We incorporate these pions into temperature and composition-dependent equations of state, either as a condensate or a thermal population. Compared to models without pions, we observe changes in the properties of cold, non-rotating neutron stars, including reductions in maximum mass, radius, and tidal deformability. We then conduct several relativistic hydrodynamical simulations of neutron star mergers using these modified equations of state. We find the inclusion of pions in general softens the equation of state, which is particularly pronounced for smaller effective pion masses. We find an increase in the dominant postmerger gravitational-wave frequency by up to 150Hz and a reduction of the threshold binary mass for prompt black-hole formation by up to $0.07M_{\odot}$. We examine empirical relationships that correlate the threshold mass or the dominant postmerger gravitational-wave frequency to the stellar parameters of nonrotating neutron stars. These correlations are formulated to extract these stellar properties from merger observations and are built based on large sets of equation of state models which do not incorporate pions. Comparing these empirical relations with our calculations including pions, we observe that they remain valid to good accuracy and justifies their use despite not accounting for the potential impact of pions. Additionally, we also address the mass ejection by neutron star mergers and observe a moderate enhancement of the ejecta mass by a few ten per cent.

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