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Ab initio calculation of hyper-neutron matter

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The equation of state (EoS) of neutron matter plays a decisive role to understand the neutron star properties and the gravitational waves from neutron star mergers. At sufficient densities, the appearance of hyperons generally softens the EoS, leading to a reduction in the maximum mass of neutron stars well below the observed values of about 2 solar masses. Even though repulsive three-body forces are known to solve this so-called "hyperon puzzle", so far performing \textit{ab initio} Monte Carlo calculations with a substantial number of hyperons has remained elusive. We address this challenge by employing Nuclear Lattice Effective Field Theory with up to 232 neutrons and 116 Λ hyperons in a finite volume. We introduce a novel auxiliary field quantum Monte Carlo algorithm, allowing us to simulate both pure neutron matter and hyper-neutron matter up to 5 times the
density of nuclear matter using a single auxiliary field without any sign oscillations. Also, for the first time in {\em ab initio} Monte Carlo calculations, we not only include $N\Lambda$ two-body and $NN\Lambda$ three-body forces, but also $\Lambda\Lambda$ and $N\Lambda\Lambda$ interactions. Consequently, we determine essential astrophysical quantities such as the neutron star mass-radius relation and confirm the existence of the universal I-Love-Q relation.

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