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Reconstructing the neutron star equation of state from observational data via automatic differentiation

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Neutron stars harbor extreme conditions unattainable in terrestrial laboratories, making them ideal candidates to study the equation of state (EoS) of strongly interacting matter. Advancements in the measurements of neutron star masses, radii and tidal deformabilities through electromagnetic and gravitational wave observations have made it feasible to add further constraints on the EoS. In this work, we present a novel method that exploits deep learning techniques to reconstruct the neutron star EoS from mass-radius (MR) observations. Our approach makes use of an unsupervised learning procedure in the Automatic Differentiation framework to optimize the EoS. Using limited mock data, we demonstrate that our proposed method has the ability to successfully reconstruct a model-independent EoS while accounting for large observational errors. We further deploy our deep learning methodology on existing MR observations, including the latest data from NICER, to infer the neutron star EoS. The reconstructed EoS band is proven consistent with conventional nuclear EoS models. Lastly, we test our results against the bounds on tidal deformability obtained from the gravitational wave event, GW170817.

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