Reconstructing Compact Objects Equation of State (EoS) via Machine and Deep Learning

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Abstract

A fundamental challenge in nuclear physics is the determination of the equation of state (EoS) of dense nuclear matter, which directly impacts our understanding of the structure and composition of compact astrophysical objects, such as neutron and quark stars. Traditionally, this problem has been approached through theoretical modeling, based on nuclear and particle physics, followed by validation against experimental data from heavy-ion collisions and, increasingly, astrophysical observations. In recent years, hybrid methodologies, combining theoretical predictions with observational information, have emerged, incorporating advanced statistical techniques, such as Bayesian inference alongside machine learning and deep learning frameworks. These approaches provide powerful tools for the interpretation and constraining of the EoS. In this work, we employ machine and deep learning regression techniques to infer the underlying equation of state from mass–radius relations of compact objects. The analysis is based on an extensive dataset of physically consistent equations of state, constructed using multimodal descriptions for neutron stars, as well as corresponding models for quark stars. By leveraging these data, the proposed framework enables the reconstruction of the EoS directly from observable properties, offering a complementary pathway to traditional approaches.