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Unveiling Neutron Star Composition and Observables: A Comprehensive Study using Deep Bayesian Neural Networks

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In the emerging field of astrophysics, understanding the intricate nature of neutron stars (NSs) and their equations of state (EoS) remains a challenging task. This talk presents an integrated approach based on deep learning and Bayesian neural networks (BNNs) to unravel the NS composition.

Our research is built upon two key studies. The first exploits BNNs' unique capability to provide prediction uncertainty measures, leveraging them to infer the proton fraction and sound speed within NS interiors, based on their macroscopic properties. A set of simulated observations, including NS radius and tidal deformability, were analysed using BNNs models developed on a dataset of ~25 K nuclear equations of state. These models were obtained through Bayesian inference within a relativistic mean-field framework. The results demonstrated a successful recovery of the NS composition with reasonable uncertainty levels.

The second study introduces a deep learning-based methodology to predict key NS observables from nuclear matter parameters. The neural network model proved to be capable of accurately replicating the intercorrelations between the symmetry energy slope, its curvature, and the tidal deformability arising from a set of physical constraints. The validity of the trained model was established using Bayesian inference, showcasing performance on par with physics-based models at a fraction of the computational cost.

This integrated research provides a comprehensive understanding of the EoS for nuclear matter at densities above the saturation density. It combines the power of deep learning and Bayesian neural networks to analyze NS observables and dense matter equations of state, paving the way for a new era of astrophysical exploration.

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