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Bayesian inference on nuclear data and neutron star observations for the nuclear equation of state

The Equation of State (EoS) of nuclear matter is related to many topics in nuclear physics. In particular, it is crucial for understanding the structure of compact objects such as neutron stars. In the conservative hypothesis of a purely nucleonic composition of neutron star matter, the EoS is fully determined in terms of the so-called nuclear matter parameters (NMPs), which, in principle, can be determined from nuclear theory and experiments, though with error bars. However, analyses that try to infer the NMPs from nuclear experiments often present one of the following limitations: (i) the control over the quality of the simultaneous reproduction of different observables is limited; (ii) independent inferences of single NMPs give poor knowledge of the correlations among parameters.

The main objective of our work is to address both limitations. Within the standard Skyrme functional ansatz, we build a reliable probability distribution for a combination of nuclear matter parameters and Skyrme parameters (which are needed to constrain all the terms of the functional) using a combined Bayesian inference of a large set of EoS-sensitive nuclear structure data. Beyond the usual ground state properties like binding energies and charge radii, we also included the much-discussed polarizabilities and parity-violating asymmetries of ^{208}Pb and ^{48}Ca, which put stringent constraints on the NMPs J and L, both crucial for the symmetry energy.

The Bayesian analysis final result is a 10-dimensional multivariate probability distribution for the NMPs and Skyrme parameters. Marginalizing the distribution over all parameters but one allows for comparison with previous simpler analyses in the literature, which will be presented during the talk.

Furthermore, the posterior distribution can be used as a prior distribution in a successive Bayesian analysis, this time using astrophysical observations as constraints. This way, this second posterior distribution of NMPs will be informed by both nuclear physics and astrophysics. We will show that the constraints from nuclear experiments are well compatible with the theoretical predictions for infinite pure neutron matter from ab initio modelling, and those constraints additionally indicate the existence of interesting structures in the EoS of neutron stars. We will discuss the final predictions on some selected static properties of neutron stars, which can be computed from the distribution of NMPs. We will devote further attention to the composition of the star crust, which is computed consistently with the star EoS within the extended Thomas-Fermi formalism.

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