Contribution ID: **108** Type: **Contributed talk**

Equation of State in the era of new nuclear physics and multimessenger constraints

Wednesday 10 July 2024 15:15 (20 minutes)

The long-sought equation of state of hadronic matter across a wide range of densities and temperatures, based on first principles with quarks and gluons i.e. quantum chromodynamics remains one of the key issues in physics. Over the past decade, a widely rich variety of data pouring in from laboratory experiments as well as astrophysical observations, including the detection of gravitational waves from binary neutron star mergers and the observations of a subsequent electromagnetic signal have raised new challenges. Simulations of these latter events based on numerical solutions of the hydrodynamic equations in General Relativity require the knowledge of the EoS of matter. Remarkable progress in the chiral effective field theory (χ-EFT) in recent years has started to provide some realistic answers. However, the perturbative momentum expansion techniques applied in χ-EFT theory break down at high densities that are relevant for the matter in these extreme astrophysical environments. Moreover, this approach is not computationally tractable for low density matter where clusters are present. The density functional theory has proven to be one of the most viable approaches to achieve these goals.

In this contribution, I will start with an overview of different types of equation of state modelling in the Bayesian formalism, to demonstrate the impact of different experimental and observational constraints. Further, I will present equations of state at finite temperature obtained with Brussels-Skyrme-on-a-Grid (BSkG) energy density functionals developed at Brussels, which are unified across the crust and core of the neutron star environment. These models have demonstrated remarkable accuracy over the whole nuclear chart on the masses, and fission barriers of nuclei, but at the same time they also satisfy recent astrophysical constraints. I will also outline the impact of our calculations at finite temperatures on the composition of the crust in the neutron stars. Our future goal is to apply these equations of state in the simulation of binary neutron star mergers.

session

H. Equation of State and Neutron Stars

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Session Classification: H. Equation of State and Neutron Stars