Executive summary of obtained results

Stage 1, year 2025

Cognitive impact: Better understanding of zero- and finite-temperature equations of state of dense matter.

In the astrophysics of compact stars, the question of the equation of state (EOS) of dense matter concerns its properties both at zero and finite temperatures. As such, we first performed a Bayesian investigation of the zero-temperature EOS of dense strongly interacting matter described by the Brussels extended Skyrme (BSk) model of effective interactions. Once this phase had been completed, we addressed the thermal behavior of a large number of BSk EOSs. All in all, our work contributes to the collective effort for a better understanding of the properties of baryonic matter over wide domains of density, proton fraction, and temperature relevant for the physics of neutron stars (NSs), core-collapse supernovae (CCSNe) and binary neutron star (BNS) mergers.

The main objective of stage 1 was to perform a number of Bayesian inferences of dense matter EOSs with nucleonic degrees of freedom, taking into account all current theoretical and experimental constraints from nuclear physics and from astrophysical observations of NSs. The non-relativistic BSk effective interaction was chosen for this purpose. The BSk interactions contain extra momentum-dependent terms that result in an increased flexibility of the model. This allows one to account for a wider range of possible behaviors of NSs' EOSs and accommodate non-monotonic density dependencies of the Landau effective masses, as predicted by advanced χEFT as well as Brueckner-Hartree-Fock *ab initio* calculations with three-body forces.

Important cataclysmic astrophysical phenomena such as CCSNe and BNS mergers crucially depend on the finite-temperature behavior of dense matter. It is well-established that the dependence of the Landau effective masses on baryon density is one of the key ingredients of the thermal response of dense matter. Most of the EOSs employed in investigations of CCSNe and/or BNS mergers have a very simple monotonic dependence of the effective masses on density. Thus, after obtaining results with non-monotonic dependencies of the effective masses on density, we focused on studying the thermal response of our BSk models.

Our key result for warm inhomogeneous matter is the presence of a thick layer of neutron-rich light isotopes deep in the inner crusts of neo-NSs. Such a layer might challenge the existence of commonly assumed "nuclear pasta" phases. It is also expected to modify the transport properties of the inner crust and alter its crystallization process. Our key result for warm homogeneous matter is that the thermal pressure can become negative at high densities, which has far-reaching implications for the stability of hot compact stars, specifically for the fate of PNSs and BNS merger remnants. We expect that EOSs featuring negative thermal pressure will lead to specific patterns in the neutrino and GW signals along with probably altered properties of the proto-NSs and BNS merger remnants.

In addition to the above-mentioned results, we have done a lot of work in preparation for stage 2 and stage 3 of the project. Specifically, major upgrades to our NSs' thermal evolution codes `NSCool 2D Rot` and `neo-NSCool` were implemented.