HK 32: Nuclear Astrophysics IV

Time: Wednesday 15:45–17:15 Location: SR 0.03 Erw. Physik

Group Report HK 32.1 Wed 15:45 SR 0.03 Erw. Physik

Equation of state and Fermi liquid properties of dense matter based on chiral EFT interactions — •Faruk Alp[1,2,3], Yannick Dietz[1,2], Kai Hebeler[1,2,3], and Achim Schwenk[1,2,3] — [1]Department of Physics, Technische Universität Darmstadt — [2]ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung GmbH — [3]Max-Planck-Institut für Kernphysik, Heidelberg

We give an update on calculations of symmetric nuclear matter and pure neutron matter obtained in many-body-perturbation theory up to third order based on various, recently developed nucleon-nucleon and three-nucleon interactions derived from chiral effective field theory. We extract empirical equation of state parameters and present estimates of the theoretical uncertainties due to neglected higher-order contributions in the many-body expansion as well as the chiral expansion of the interactions. Furthermore, we discuss a Fermi liquid calculations for pure neutron matter and present results for the Landau parameters, quasiparticle effective mass, and the speed of sound.

* Funded by the ERC Grant Agreement No. 101020842 and by the DFG – Project-ID 279384907 – SFB 1245.

HK 32.2 Wed 16:15 SR 0.03 Erw. Physik

Equation of state effects in core-collapse supernova simulations — •Finia P. Jost[1], Andre da Silva Schneider[2], Gerard Navo[3], Yeunhwan Lim[4], Sabrina Huth[1], Almudena Arcones[1,5,6], and Achim Schwenk[1,6] — [1]Institut für Kernphysik, Technische Universität Darmstadt, Darmstadt, Germany — [2]Departamento de Física, Universidade Federal de Santa Catarina, Florianópolis, Brazil — [3]Departament d'Astronomia i Astrofisica, Universitat de Valencia, Valencia, Spain — [4]Department of Physics, Yonsei University, Seoul, South Korea — [5]GSI Helmholtzzentrum fuer Schwerionenforschung GmbH, Darmstadt, Germany — [6]Max-Planck-Institut fuer Kernphysik, Heidelberg, Germany

The equation of state (EOS) of dense matter remains uncertain, especially at higher densities. The dynamics of core-collapse supernovae and the properties of newly formed proto-neutron stars directly depend on the state of matter at these high densities. We provide new EOS tables based on the EOS models of Huth et al. 2021 covering the necessary range in density, temperature, and electron fraction to be used in astrophysical simulations. The EOS are consistent with all currently available constraints from theoretical and experimental nuclear physics as well as observations of neutron stars. We systematically vary cold nuclear matter properties within their uncertainties and explore their impact in simulations of core-collapse supernovae. Additionally, we explore the impact of the new prescription of the density-dependent effective mass of nucleons, which governs the thermal nucleonic contribution to the EOS.

HK 32.3 Wed 16:30 SR 0.03 Erw. Physik

Perturbative quantum chromodynamics constraints on the dense matter equation of state in a Bayesian inference framework — •Anna Hensel[1], Melissa Mendes[1,2,3], Isak Svensson[1,2,3], Kai Hebeler[1,2,3], and Achim Schwenk[1,2,3] — [1]Technische Universität Darmstadt, Department of Physics — [2]ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung GmbH — [3]Max-Planck-Institut für Kernphysik, Heidelberg

We investigate how perturbative quantum chromodynamics (pQCD) calculations at high densities constrain equation of state (EOS) posteriors from a Bayesian inference framework at neutron-star densities. To construct the EOS we use calculations from chiral effective field theory and implement a polytropic (PP) and a speed of sound (CS) high-density extension. The EOS is further constrained by neutron star observations, including gravitational-wave and NICER measurements. We find that pQCD calculations have a small effect on the posteriors in the CS case, and no noticable effect in the PP case.

*Funded by ERC Grant Agreement No. 101020842

HK 32.4 Wed 16:45 SR 0.03 Erw. Physik

Determining proto-neutron stars' minimal mass with chirally constrained nuclear equations of state — •Selina Kunkel, Stephan Wystub, and Jürgen Schaffner-Bielich — Institut für Theoretische Physik, Goethe Universität, Frankfurt am Main, Germany

The minimal masses and radii of proto-neutron stars during different stages of their evolution are investigated. We focus on two stages, directly after the supernova shock wave moves outwards, when neutrinos are still captured in the core and the lepton per baryon ratio is fixed to $Y_L = 0.4$, and a few seconds afterwards, when all neutrinos have left the star. We find for the neutrino-trapped case higher minimal masses than for the case when neutrinos have left the proto-neutron star. Thermal effects, here in the form of a given constant entropy per baryon s, have a smaller effect on increasing the minimal mass. The minimal proto-neutron star mass for the first evolutionary stage with $Y_L = 0.4$ and $s = 1$ amounts to $M_{min} \sim 0.62 M_\odot$ and for the stage without neutrinos and $s = 2$ to $M_{min} \sim 0.22 M_\odot$ rather independent on the nuclear equation of state used. We demonstrate that there is a universal relation for the increase of the proto-neutron star minimal mass with the lepton fraction for all nuclear equations of state used. We discuss a possible extension of our investigation for studying the appearance of color superconducting phases during proton-neutron star evolution.

HK 32.5 Wed 17:00 SR 0.03 Erw. Physik

Uncertainty quantification for the nuclear equation of state — •Hannah Göttling[1,2], Kai Hebeler[1,2,3], and Achim Schwenk[1,2,3] — [1]Technische Universität Darmstadt, Department of Physics — [2]ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung GmbH — [3]Max-Planck-Institut für Kernphysik, Heidelberg

The nuclear equation of state (EOS) characterizes the properties of matter as a function of density, temperature, and proton fraction, and thus connects microscopic strong interaction calculations with descriptions of compact objects in astrophysics. Focusing on the low-energy regime, chiral effective field theory (EFT) provides a systematically improvable description of nuclear systems. With Gaussian processes (GPs) we introduce a tool to realize non-parametric evaluations of the EOS, considering correlations along independent variables. This further enables us to calculate derivatives to provide thermodynamic quantities. Besides constructing an emulator we use GPs for a statistical description of chiral expansion coefficients and apply Bayesian statistics to assess the EFT truncation errors. With that we are able to provide the nuclear EOS for nuclear matter in β-equilibrium with propagated chiral uncertainties.

Funded by the research cluster ELEMENTS (Project ID 500/10.006) and by the DFG – Project-ID 279384907 – SFB 1245.