HK 73: Nuclear Astrophysics

Time: Thursday 16:30–18:00 Location: H-ZO 60

Group Report HK 73.1 Th 16:30 H-ZO 60

A Supernovae Equation of State with Light and Heavy Clusters — •Stefan Typel[1,2], Gerd Röpke[3], Thomas Klähn[4], David Blaschke[5], and Hermann Wolter[6] — [1]Excellence Cluster Universe, TU München — [2]GSI Darmstadt — [3]Uni Rostock — [4]Argonne National Laboratory — [5]Uni Wrocław — [6]LMU München

The equation of state of dense matter is an essential ingredient in astrophysical models of supernovae and compact stars. At densities below nuclear saturation and not too high temperatures, many-body correlations have a considerable impact on the thermodynamical properties. The appearance of light and heavy clusters changes the chemical composition of the system. Combining a relativistic mean-field model with density-dependent couplings and a generalized Beth-Uhlenbeck approach, it is possible to describe the dissolution of the clusters with increasing density and temperature in a microscopic, self-consistent model. The parameters can be constrained by properties of finite nuclei, neutron stars and heavy-ion collisions. Particular attention is paid to the thermodynamical consistency and the construction of phase transitions.

HK 73.2 Th 17:00 H-ZO 60

A Statistical Model for Supernova Matter — •Matthias Hempel[1] and Jürgen Schaffner-Bielich[2] — [1]Institut für Theoretische Physik, Goethe-Universität, Max-von-Laue-Str. 1, 60438 Frankfurt am Main, Germany — [2]Institut für Theoretische Physik, Ruprecht-Karls-Universität, Philosophenweg 16, 69120 Heidelberg, Germany

The equation of state and the composition of hot hadronic matter is described by an ensemble of nuclei and interacting nucleons in nuclear statistical equilibrium. A relativistic mean field model is applied for the nucleons. The masses of the nuclei are taken from nuclear structure calculations which are based on the same nuclear Lagrangian. For known nuclei experimental data is used directly. To achieve a good description of the transition to uniform nuclear matter a thermodynamic consistent model is developed which implements excluded volume effects. The model is suitable for the entire range of conditions (T, n_B, Y_p) in core-collapse supernovae and a complete equation of state table is presented. Good agreement with other commonly used models based on the single nucleus approximation is found. Regarding the composition the importance of the statistical treatment and the nuclear distributions is illustrated. The role of shell effects is investigated. Special emphasis is put on the light clusters which are only poorly represented by alpha particles under certain conditions. As a first application the equation of state is used to study the evolution of cooling proto-neutron stars.

HK 73.3 Th 17:15 H-ZO 60

Signals of the QCD phase transition in core-collapse supernovae — Irina Sagert[1], Matthias Hempel[1], •Giuseppe Pagliara[2], Jurgen Schaffner-Bielich[2], Tobias Fischer[3], Anthony Mezzacappa[4], Friederich Karl Thielemann[3], and Matthias Liebendorfer[3] — [1]Institut für Theoretische Physik, Goethe Universität, *Max-von-Laue-Str. 1, 60438 Frankfurt am Main, Germany — [2]Institut für Theoretische Physik, Ruprecht-Karls-Universität,*Philosophenweg 16, 69120 Heidelberg, Germany — [3]Department of Physics, University of Basel, Klingelbergstr. 82, 4056 Basel, Switzerland — [4]Physics Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831

We explore the implications of the QCD phase transition during the postbounce evolution of core-collapse supernovae. Using the MIT bag model for the description of quark matter and assuming small bag constants, we model phase transitions that occur during the early postbounce evolution. We show that the phase transition produces a second shock wave which triggers a delayed supernova explosion. If such a phase transition happens in a future galactic supernova, its existence and properties should become observable as a second peak in the neutrino signal that is accompanied by significant changes in the energy of the emitted neutrinos. In contrast to the first neutronization burst, this second neutrino burst is dominated by the emission of anti-neutrinos.

HK 73.4 Th 17:30 H-ZO 60

Nuclear pasta with a touch of quantum — •Klaas Vantournhout, Natalie Jachowicz, and Jan Ryckebusch — Department of Subatomic and Radiation Physics, Ghent University, Proeftuinstraat 86, B-9000 Gent, Belgium

At densities of about 10^{14}g/cm^3, neutronrich matter arranges itself in a variety of complex shapes. It is suggested that these slab and rod-like structures, dubbed nuclear pasta, appear in the crust of neutron stars as well as in the centre of core-collapse supernovae, thereby influencing the dynamics of the process. For the study of these low-energy excitations, classical molecular dynamic techniques (CMD) are used [1,2].

Fermionic molecular dynamics (FMD), a formalism used to model nuclei and heavy-ion collisions, rises the description of nuclear matter to a quantum mechanical level by adding antisymmetrisation, spin, isospin and probability distributions to a CMD-like formalism [3]. The technique presented here is an extension of FMD to model bulk fermionic matter. Through the use of block-Toeplitz matrices and Jacobi-Theta functions it becomes feasible to describe infinite dimensional fermion systems [4]. In practice this is achieved by importing periodic boundary conditions into FMD giving rise to a quantum dynamical description of nuclear matter. Results illustrating the behaviour of free Fermi gases and alpha clustering will be presented.

[1] G. Watanabe et al., Phys. Rev. C **69**, 055805 (2004).
[2] C.J. Horowitz et al., Phys. Rev. C **72**, 035801 (2005).
[3] H. Feldmeier and J. Schnack, Rev. Mod. Phys **72**, 655-688 (2000).
[4] K. Vantournhout et al. (in preparation)

HK 73.5 Th 17:45 H-ZO 60

Beta decay and muon capture rates in a self-consistent relativistic framework — •Tomislav Marketin[1], Nils Paar[1], Tamara Nikšić[1], Dario Vretenar[1], and Peter Ring[2] — [1]Physics Department, Faculty of Science, University of Zagreb, Croatia — [2]Physik-Department der Technischen Universität München, D-85748 München, Germany

A fully consistent calculation of muon capture and beta decay rates is presented, based on a microscopic theoretical framework describing the semileptonic weak interaction processes. Nuclear ground state is determined using the Relativistic Hartree-Bogoliubov (RHB) model with density dependent meson-nucleon coupling constants, and transition rates are calculated via proton-neutron relativistic quasiparticle RPA using the same interaction as in the RHB equations. Muon capture rates are calculated for a wide range of nuclei along the valley of stability, from ^{12}C to ^{244}Pu, with accuracy of approximately 30%, using the interaction DD-ME2[1]. Previous studies of beta decay rates have only taken into account Gamow-Teller transitions[2]. We extend this approach by including forbidden transitions and systematically study their contribution to decay rates of exotic nuclei along the r-process path, which are important for constraining the conditions in which nucleosynthesis takes place.

[1] T. Marketin, N. Paar, T. Nikšić and D. Vretenar, submitted to Phys. Rev. C (2008) (*arXiv:nucl-th\0812.1947*).
[2] T. Marketin, D. Vretenar and P. Ring, Phys. Rev. C 75, 024304 (2006).