HK 62: Nuclear Astrophysics 5

Time: Thursday 17:00–19:00 Location: P/H1

Group Report HK 62.1 Thu 17:00 P/H1

The COBRA experiment - Status report — •Thomas Quante for the COBRA-Collaboration — Technische Universität Dortmund, Otto-Hahn-straße 4, 44221 Dortmund

COBRA is a next-generation experiment searching for neutrinoless double beta ($0\nu\beta\beta$) decay using CdZnTe semiconductor detectors. The main focus is on 116Cd, with a Q-value of 2813.5 keV well above the highest naturally occurring gamma lines. By measuring the half-life of the $0\nu\beta\beta$ decay, it is possible to clarify the nature of the neutrino as either Dirac or Majorana particle and furthermore to determine the effective Majorana mass.

For this purpose a detector array made up of 64 Cadmium-Zinc-Telluride (CdZnTe) semiconductor detectors in coplanar grid configuration was designed and realised at the Gran Sasso Underground laboratory (LNGS) in Italy. It is used to gather information about the long term stability in low background operation and the identification of potential background components.

Simulations of the whole demonstrator setup are ongoing to reproduce the measured spectra for each detector. As the "detector=source" principle, the 0nbb signal can happen all over the detector. Therefore, events that occur on the detector surface are most likely background events. The pulse shape analysis gives the opportunity to reject these events, which lowers the the overall background in the region of interest by more than one order of magnitude. In this talk an overview of the detector technology and analysis techniques is given. In addition the recent progress and future plans will be discussed.

HK 62.2 Thu 17:30 P/H1

Long-time hydrodynamical simulations of core-collapse supernovae — •Carlos Mattes[1] and Almudena Arcones[1,2] — [1]Institut für Kernphysik, TU Darmstadt — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH

Core-collapse supernovae are one of the major contributors to the chemical enrichment in the universe: they eject elements that were synthesized during the life of stars (e.g., oxygen and carbon) and they produce new and heavier elements (e.g., 1/3 of the iron in our galaxy). We will present the first long-time hydrodynamic simulations with FLASH code [1] that follow the supernova explosion from the collapse phase to several seconds after bounce. Our neutrino-driven explosions are triggered by enhancing the neutrino energy deposition [2]. In order to calculate the explosive nucleosynthesis, we have included a reduced alpha network and two equations of state that allow us to study regions from nuclear density to very low density.

[1] Couch S. M. 2013, ApJ, 775, 35
[2] O'Connor E. & Ott C. D. 2010, CQGra, 27, 114103

HK 62.3 Thu 17:45 P/H1

Impact of bremsstrahlung on the neutrinosphere for muon and tau neutrinos* — •Hannah Yasin[1], Almudena Arcones[1,2], and Alexander Bartl[1] — [1]Institut für Kernphysik, TU Darmstadt, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany

Core-collapse supernovae present a challenging and exciting problem that strongly depends on all forces (strong, weak, electromagnetism, and gravity). Neutrinos, although weakly interacting, are key to transporting energy and momentum. Therefore, detailed treatment of neutrino reactions is critical to understand these high energy events. We have studied the impact of different neutrino reactions on the position of the neutrinosphere (i.e., region where neutrinos decouple from matter). Since the density in this region is high the effect of nuclear interactions has to be considered for bremsstrahlung [1]: $N + N \to N + N + \nu + \bar{\nu}$. We have employed new, improved approaches [2] to calculate the inverse process and show the effect on the position of the neutrinosphere for muon and tau neutrinos.

[1] S. Hannestad and G. Raffelt, Astrophysical Journal 507 (1998) 339.
[2] A. Bartl, C. J. Pethick, and A. Schwenk, Physical Review Letters 113 (2014) 081101.

* Supported by Helmholtz-University Young Investigator grant No. VH-NG-825.

HK 62.4 Thu 18:00 P/H1

Neutron star equations of state with optical potential constraint — •Sofija Antic[1,2] and Stefan Typel[1] — [1]GSI, Darmstadt, Germany — [2]TU Darmstadt, Germany

Nuclear matter and compact neutron stars are studied in the framework of an extended relativistic mean-field (RMF) model that includes higher-order derivative and density dependent couplings of nucleons to the meson fields. Generalized Euler-Lagrange equations follow from the principle of least action and the most general expresions for current and energy-momentum tensor are derived. The equation of state (EoS) of infinite nuclear matter is obtained for different non-linear derivative coupling functions. From experimental constraints on the optical potential the appropriate energy dependence of the regulator functions is chosen. The thermodynamical consistency of the model is demonstrated.

Spherical, non-rotating stars are described with the new EoS considering charge neutrality and β-equilibrium conditions. The stellar structure is calculated by solving the Tolman-Oppenheimer-Volkov (TOV) equations and the results for neutron stars are shown in terms of mass-radius relations.

This work is supported by the Helmholtz Association (HGF) through the Nuclear Astrophysics Virtual Institute (NAVI, VH-VI-417).

HK 62.5 Thu 18:15 P/H1

Role of nuclear reactions on stellar evolution of intermediate-mass stars — •Heiko Möller[1], Samuel Jones[2], Tobias Fischer[3], Raphael Hirschi[4], Ken'ichi Nomoto[5], and Gabriel Martínez-Pinedo[1] — [1]TU Darmstadt — [2]University of Victoria — [3]Uniwersytet Wrocławski — [4]Keele University — [5]Kavli IPMU

The evolution of intermediate-mass stars (8 - 12 solar masses) represents one of the most challenging subjects in nuclear astrophysics. Their final fate is highly uncertain and strongly model dependent. They can become white dwarfs, they can undergo electron-capture or core-collapse supernovae or they might even proceed towards explosive oxygen-burning and a subsequent thermonuclear explosion. We believe that an accurate description of nuclear reactions is crucial for the determination of the pre-supernova structure of these stars and show that weak rates involving sd-shell nuclei are of particular importance. We argue that due to the possible development of an oxygen-deflagration, a hydrodynamic description has to be used. We implement a nuclear reaction network with $\sim$200 nuclear species into our implicit hydrodynamic code AGILE. The reaction network considers all relevant nuclear electron captures and beta-decays. For selected relevant nuclear species, we include a set of updated reaction rates based on shell-model calculations, for which we discuss the role for the evolution of the stellar core, at the example of selected stellar models. We find that the final fate of these intermediate-mass stars depends sensitively on the density threshold for weak processes that deleptonize the stellar core.

This work is supported by the DFG through contract SFB 634.

HK 62.6 Thu 18:30 P/H1

Neutrino interactions with supernova matter* — •Alexander Bartl[1,2], Christopher J. Pethick[3,4], Achim Schwenk[2,1], and Maria Voskresenskaya[2,1] — [1]Institut für Kernphysik, Technische Universität Darmstadt — [2]ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung GmbH — [3]The Niels Bohr International Academy, The Niels Bohr Institute, Copenhagen, Denmark — [4]NORDITA, Royal Institute of Technology and Stockholm University, Stockholm, Sweden

Neutrino pair bremsstrahlung and absorption ($NN \leftrightarrow NN\nu\bar{\nu}$) as well as inelastic scattering of neutrinos ($NN\nu \leftrightarrow \nu NN$) are of great relevance for the generation of and energy transport by neutrinos in core-collapse supernovae. In this talk, we will present a unified treatment of the energy transfer due to inelastic neutrino scattering on interacting nucleons and due to nuclear recoil. We will show that nuclear interaction effects can be a significant contribution to the total energy transfer and hence should be included in supernova simulations. In addition, we discuss the impact of neutrino rates involving strongly interacting nucleons in these simulations.

*This work was supported by the Studienstiftung des Deutschen Volkes, ARCHES, the Helmholtz Alliance HA216/EMMI and the ERC Grant No. 307986 STRONGINT.

HK 62.7 Thu 18:45 P/H1

Neutrino-driven winds from neutron star merger remnants*

— •Albino Perego[1], Almudena Arcones[1], Ruben Cabezon[2], Roger Kaeppeli[3], Oleg Korobkin[4], Dirk Martin[1], and Stephan Rosswog[4] — [1]Institut für Kernphysik, Technische Universität Darmstadt — [2]Physics Department, University of Basel, Switzerland — [3]Seminar for applied Mathematics, ETH Zürich, Switzerland — [4]The Oskar Klein Centre, Department of Astronomy, AlbaNova, Stockholm University, Sweden

During the merger of two neutron stars, matter can be ejected in the interstellar medium through different channels. The ejection mechanism, as well as the expansion timescale, can influence deeply the matter properties and, eventually, the subsequent nucleosynthesis. In this talk, I will present results regarding the formation and the properties of a neutrino-driven wind in the aftermath of a binary neutron star merger, in presence of a long living hyper massive neutron star [1]. Implications in terms of nucleosynthesis, electromagnetic counterparts and gamma-ray burst engine will be also discussed [1,2].

[1] A. Perego et al., 2014, MNRAS, 443, 3134.
[2] D. Martin et al., in preparation.

* Supported by Helmholtz-University Young Investigator grant No. VH-NG-825.