HK 25: Nukleare Astrophysik II

Time: Tuesday 16:30–19:00 Location: HS3

Group Report HK 25.1 Tue 16:30 HS3

Composition, structure, and thermal evolution of magnetized and rotating compact stars. — •Rodrigo Picanco Negreiros[1], Stefan Schramm[1], Veronica Dexheimer[2], Fridolin Weber[3], Igor Mishustin[1,4], and Torsten Schuerhoff[1] — [1]Frankfurt Institute for Advanced Studies — [2]Gettysburg College — [3]San Diego State University — [4]The Kurchatov Institute

In this work we will report our findings on our research on the composition, structure and thermal evolution of compact objects. We use observed data of compact stars to probe matter at high-density and low temperatures. In our work we investigate the three major fronts of compact star research: the microscopic composition, the macroscopic structure, and the thermal evolution. Our theoretical predictions are compared to observed data, which allows us to assess the validity of the models. We explore a variety of microscopic models, with special attention given to a particular hybrid star model, in which the quark and hadronic phase of the star is described by a Flavor SU(3) sigma-omega model. We also consider the effects of a magnetic field on the microscopic composition, and the consequences to the structure and thermal evolution of the star. Since compact stars may be rotating very rapidly, we also investigate the effects of rotation on the structure of these objects. Furthermore, the changes in structure that follow the spin evolution of the star is also investigated. We also show our results for the thermal evolution of spinning down neutron stars. Finally we discuss the possible connection between differentially rotating quark stars and Central Compact Objects.

HK 25.2 Tue 17:00 HS3

Quark matter in massive neutron stars — •Simon Weissenborn[1], Irina Sagert[2], Giuseppe Pagliara[1], Matthias Hempel[3], and Jürgen Schaffner-Bielich[1] — [1]Institute for Theoretical Physics, Ruprecht-Karls University, Philosophenweg 16, Heidelberg, D-69120 — [2]Frankfurt Institute for Advanced Studies, Goethe University, Ruth-Moufang Str. 1, Frankfurt, D-60438 — [3]Department of Physics, University of Basel, Klingelbergstrasse 82, Basel, CH-4056

The recent observation of the pulsar PSR J1614-2230 with a mass of 1.97 solar masses gives a strong constraint on the nuclear matter equation of state. We explore the parameter ranges for a parameterized equation of state for quark stars. We find that such massive objects made of absolutely stable strange quark matter can reach the new constraint only if effects from the strong coupling constant and color superconductivity are considered. Also hybrid stars are able to be massive but a pure quark matter core appears only if the hadronic equation of state is stiff. A soft hadronic equation of state would imply that hybrid stars contain just a core of quark hadron mixed phase. In general, due to the softening of the equation of state at the quark-hadron phase transition the masses of hybrid stars stay below the ones of hadronic and pure quark stars.

HK 25.3 Tue 17:15 HS3

Nuclear matter equation of state below saturation density in a relativistic mean-field model with new constraints on the couplings — •Maria Voskresenskaya[1] and Stefan Typel[1,2] — [1]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt — [2]Excellence Cluster Universe, TU München, Garching

The description of neutron star matter requires the knowledge of the equation of state (EoS) in a wide range of densities. In this work we are trying to improve the phenomenological description of nuclear matter within a generalized relativistic mean field (RMF) model with density dependent coupling constants. The couplings are well constrained only near the saturation density of nuclear matter and are extrapolated to smaller and higher densities. A comparison of the RMF equation of state of nuclear matter with the virial expansion leads to new constraints for the couplings at small densities. A new parametrization of density dependent couplings is suggested based on these constraints and various effects are discussed that are important for the thermodynamical properties of matter below saturation.

HK 25.4 Tue 17:30 HS3

Response functions of superfluid neutron matter — •Jochen Keller and Armen Sedrakian — Institut für Theoretische Physik, Goethe Universität Frankfurt/Main, 60438 Frankfurt/Main

We investigate the response of pair-correlated neutron matter under conditions relevant to neutron stars to external weak probes and compute its neutrino emissivity in vector and axialvector channels. To derive the response functions we sum up an infinite chain of particle-hole ladder diagrams within finite-temperature Green's function theory. The polarization tensor of matter is evaluated in the limit of small momentum transfers. The calculated neutrino emission via the weak neutral current processes of pair-breaking and recombination of Cooper-pairs in neutron stars causes a cooling of their baryonic interior, and represents an important mechanism for the thermal evolution of the star within a certain time domain.

HK 25.5 Tue 17:45 HS3

Neutrino interactions in hot strange quark matter — •Andreas Lohs[1] and Jürgen Schaffner-Bielich[2] — [1]Institut für Theoretische Physik, Johann Wolfgang Goethe-Universität, Max von Laue-Str. 1, D-60438 Frankfurt, Germany — [2]Institut für Theoretische Physik, Ruprecht-Karls-Universität, Philosophenweg 16, D-69120, Heidelberg, Germany

Recent merger simulations pointed out the possibility of the formation of compact stars or accretion disks composed by hot strange quark matter with temperatures above 10 MeV. The dominant cooling mechanisms of these objects is neutrino emission. Neutrino transport properties for large temperatures are therefore needed since to date only calculations for small temperatures were considered for the late cooling of compact stars.

We calculate the neutrino emissivities associated with electron capture by up-quark as well as d-quark decay. We show that, at variance with previous calculations, they differ from each other up to three orders of magnitude in chemical equilibrium at temperatures of a few MeV.

Furthermore we proove that positron capture is the dominant anti-neutrino producing reaction at high temperatures.

Finally we provide some examples of cooling of strange quark matter for merger environments and discuss the possible connections with short gamma ray bursts.

HK 25.6 Tue 18:00 HS3

Resonanzstärken in der ^{40}Ca(α,γ)^{44}Ti-Reaktion — •Konrad Schmidt[1,2], Chavkat Akhmadaliev[1], Michael Anders[1], Daniel Bemmerer[1], Konstanze Boretzky[3], Antonio Caciolli[4], Zoltán Elekes[1], Zsolt Fülöp[5], György Gyürky[5], Roland Hannaske[1], Arnd Junghans[1], Michele Marta[1], Ronald Schwengner[1], Tamás Szücs[5], Andreas Wagner[1] und Kai Zuber[2] — [1]Forschungszentrum Dresden-Rossendorf (FZD), Dresden — [2]TU Dresden — [3]GSI, Darmstadt — [4]INFN Padua, Italien — [5]ATOMKI, Debrecen, Ungarn

Das Nuklid ^{44}Ti (Halbwertszeit 59 Jahre) wird in Supernovae erzeugt. Die γ-Strahlung aus seinem Zerfall lässt sich in weltraumgestützten γ-Teleskopen nachweisen und kann als Werkzeug zum Test von Supernova-Modellen genutzt werden. Hierfür ist eine genaue Kenntnis der Kernreaktionsraten für die Erzeugung und Zerstörung von ^{44}Ti erforderlich. Die ^{40}Ca(α,γ)^{44}Ti-Reaktion dominiert die Erzeugung von ^{44}Ti. Ihre Rate wird von einer Vielzahl von Resonanzen bestimmt. Um präzise Daten zu gewinnen, wurde die Stärke des Resonanztripletts bei 4.5 MeV α-Energie am Dresdner 3 MV Tandetron sowohl mittels in-beam γ-Spektrometrie als auch durch eine Aktivierungsmessung im Felsenkeller-Niederniveaumesslabor gemessen. Eine Untersuchung der bestrahlten Proben mittels Beschleunigermassenspektrometrie ist geplant. – Gefördert von der EU (FP7-SPIRIT 227012) und der DFG (BE 4100/2-1).

HK 25.7 Tue 18:15 HS3

59Fe(n,γ)60Fe measured by Coulomb Dissociation — •Tanja Heftrich for the s389-Collaboration — University of Frankfurt, Germany

One of the fundamental signatures for active nucleosynthesis in our galaxy is the observation of long-lived radioactive elements using γ-ray observatories such as INTEGRAL. Of particular importance are the two long-lived radioactive isotopes ^{26}Al and ^{60}Fe whose production is thought to be associated with the nucleosynthesis in hot carbon or oxygen shell burning in massive pre-supernova stars and in the

subsequent shockfront driven explosive nucleosynthesis of type II supernovae. While the reactions of ^{26}Al has been studied extensively, very little is known about the reactions associated with the nucleosynthesis of ^{60}Fe. The production rate ^{59}Fe(n,γ)^{60}Fe is difficult to measure directly because of the short half-life of ^{59}Fe ($t_{1/2}$=44.5 d). Coulomb dissociation measurements of ^{59}Fe and ^{60}Fe were performed at the R3B/LAND Setup at GSI. The unstable iron isotopes were produced by fragmentation of a 660 AMeV primary beam of ^{64}Ni on a 4 g/cm2 Be target. The dissociation cross section ^{60}Fe(γ, n)^{59}Fe is important to study the inverse neutron capture process via detailed balance. In order to prove this method, ^{59}Fe(γ, n)^{58}Fe was studied to determine the already directly measured ^{58}Fe(n,γ)^{59}Fe cross section. The astrophysical motivation, an overview of the experimental setup and first results of the measurements will be presented. This project is supported by the HGF Young Investigator Project VH-NG-327.

HK 25.8 Tue 18:30 HS3

Search for Supernova ^{60}Fe in the Earth's Microfossil Record — •Shawn Bishop[1], Peter Ludwig[1], Thomas Faestermann[1], Gunther Korschinek[1], Georg Rugel[1], and Ramon Egli[2] — [1]Fakultät für Physik, Technische Universität München, James-Franck-Straße 1, D-85747 Garching, Germany — [2]Department of Earth and Environmental Sciences, Ludwig-Maximilians University, Theresienstrasse 41, D-80333 Munich, Germany

Approximately 2.8 Myr before the present, our planet was subjected to the debris of a supernova explosion. The terrestrial proxy for this event was the discovery of live atoms of ^{60}Fe in a deep-sea ferromanganese crust. The signature for this supernova event should also reside in magnetite (Fe_3O_4) microfossils produced by magnetotactic bacteria extant at the time of the Earth-supernova interaction, provided the bacteria preferentially uptake iron from fine-grained iron oxides and ferric hydroxides. Using estimates for the terrestrial supernova ^{60}Fe flux, combined with our empirically derived microfossil concentrations of a deep-sea drill core, we deduce a conservative estimate of the ^{60}Fe fraction as $^{60}\mathrm{Fe/Fe} = 3.6 \times 10^{-15}$. This value sits comfortably within the sensitivity limit of present accelerator mass spectroscopy capabilities. The implication is that a biogenic signature of this cosmic event resides, and is detectable, in the Earth's fossil record.

In this talk we describe this idea in further detail and present our magnetic scanning data from a Pacific Ocean drill core (provided by the Ocean Drilling Program, ODP) that allows us to quantify the mass concentration of Fe within the microfossils.

HK 25.9 Tue 18:45 HS3

Neutron stars with small radii - the role of Delta resonances — •Torsten Schürhoff — Institut für Theoretische Physik, Goethe Universität Frankfurt/Main, 60438 Frankfurt/Main, FIAS

Recent neutron star observations suggest that the masses and radii of neutron stars may be smaller than previously considered, which would disfavor a purely nucleonic equation of state (EoS). In our model, we use a flavor SU(3) sigma model that includes Δ resonances and hyperons in the EoS. We find that if the coupling of the Δ resonances to the vector mesons is slightly smaller than that of the nucleons, we can reproduce both the measured mass-radius relationship and the extrapolated EoS.