HK 6: Nuclear Astrophysics I

Time: Monday 15:00–16:30 Location: SR 0.03 Erw. Physik

Group Report HK 6.1 Mon 15:00 SR 0.03 Erw. Physik
Calibrated Nebular Emission Lines from Lanthanides — •Andreas Flörs[1], Ricardo Silva[2], and Gabriel Martínez-Pinedo[1] — [1]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany — [2]Laboratório de Instrumentação e Física Experimental de Partículas (LIP), Lisboa, Portugal

With the detection of multiple neutron-star merger events in the last few years, the need for a more comprehensive understanding of nuclear and atomic properties as well as radiative transfer has become increasingly important. Despite our current understanding, there are still large discrepancies in the opacities, leading to variations in the location and strength of spectral features in radiative transfer models and preventing a firm identification of r-process products.

We report on calibrated large-scale atomic structure calculations of all singly and doubly ionised lanthanides. We use the atomic structure to compute forbidden transitions, which become the main cooling mechanism after sim1 week in the evolution of the kilonova. Using these lines, we employ radiative transfer models to predict the nebular spectrum, which can be compared to observations with the JWST. We show that compared to early phase spectra, the nebular phase offers spatially separated features, which can be used to identify individual elements synthesised in the r-process.

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HK 6.2 Mon 15:30 SR 0.03 Erw. Physik
Impact of hyperons on the equation of state of dense matter — •Samet Dokur[1], 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 study the effects of hyperons on properties of dense matter using many-body perturbation theory and interactions derived within chiral effective field theory. Our goal is to systematically incorporate hyperon-nucleon and hyperon-nucleon- nucleon interactions up to next-to-leading order in our existing many-body framework, which in its current state allows to compute the equation of state of dense matter based on nucleon- nucleon and three-nucleon interactions up to N^{3}LO. In this talk, I will present the many-body framework, discuss the challenges involved in treating hyperonic interactions in many-body calculations, and present first results for the equation of state of neutron-rich matter, including calculations of the chemical potentials of the different particle species.

HK 6.3 Mon 15:45 SR 0.03 Erw. Physik
Hyperons in neutron star mergers — •Hristijan Kochankovski[1,2], Sebastian Blacker[3,4], Andreas Bauswein[4,5], Angels Ramos[2], Laura Tolos[6,7,8], and Georgios Lioutas[4] — [1]Departament de Física Quàntica i Astrofísica and Institut de Ciències del Cosmos, Universitat de Barcelona, Martí i Franquès 1, 08028, Barcelona, Spain — [2]Faculty of Natural Sciences and Mathematics-Skopje, Ss. Cyril and Methodius University in Skopje, Arhimedova, 1000 Skopje, Macedonia — [3]Institut für Kernphysik, Technische Universität Darmstadt, 64289 Darmstadt, Germany — [4]GSI Helmholtzzentrum für Schwerionenforschung, Planckstraße 1, 64291 Darmstadt, Germany — [5]Helmholtz Research Academy Hesse for FAIR (HFHF), Campus Darmstadt, 64291 Darmstadt, Germany — [6]Institute of Space Sciences (ICE, CSIC), Campus UAB, Carrer de Can Magrans, 08193 Barcelona, Spain — [7]Institut d'Estudis Espacials de Catalunya (IEEC), 08860 Castelldefels (Barcelona), Spain — [8]Frankfurt Institute for Advanced Studies, Ruth-Moufang-Str. 1, 60438 Frankfurt am Main, Germany

We study the influence of hyperons on neutron star mergers. Using a large sample of hyperonic equations of state, we make a systematic analysis of their effects. We find that during the post-merger phase of the binary neutron star collision, the average temperature is lower and the maximum density of the hot medium to be higher when they are present in matter. In addition, we also study hyperonic imprints onto ejected mass, secondary peaks, and threshold mass before collapse are. Our findings are of special interest as a venue for answering the question of the composition of ultra dense matter.

HK 6.4 Mon 16:00 SR 0.03 Erw. Physik
Color Superconductivity in Compact Stars with RG-Consistent NJL Model — •Ishfaq Ahmad Rather[1], Hosein Gholami[2], Marco Hofmann[2], Michael Michael Buballa[2,3], and Jürgen Schaffner-Bielich[1] — [1]Institute of Theoretical Physics, Goethe University, Frankfurt am main — [2]Technische Universität Darmstadt, Fachbereich Physik, Institut für Kernphysik, Theoriezentrum, Schlossgartenstr. 2, D-64289 Darmstadt, Germany — [3]Helmholtz Forschungsakademie Hessen für FAIR (HFHF), GSI Helmholtzzentrum für Schwerionenforschung, Campus Darmstadt, D-64289 Darmstadt, Germany

We analyze the renormalization group-consistent (RG-consistent) three-flavor color-superconducting Nambu-Jona-Lasinio (NJL) model to explore possible compact star configurations, focusing primarily on quark stars. By varying the vector (η_V) and diquark (η_D) couplings, we study their effects on the equation of state (EoS), speed of sound, diquark gap, and mass-radius relations.

Our results show that stable color-flavor-locked (CFL) phases often dominate the core of maximum-mass stars, spanning several kilometers in radius. For other cases, the two-flavor color-superconducting (2SC) branch becomes unstable before the CFL transition density. For neutron-star densities, the squared speed of sound reaches up to $c_s^2 \sim 0.6$. Hybrid stars constructed with these models suggest early hadron-quark transitions, impacting tidal deformability at 1.4 $M_\odot$. We constrain NJL parameters using the $2.0 M_\odot$ mass limit and find the resulting EoS consistent with astrophysical measurements.

HK 6.5 Mon 16:15 SR 0.03 Erw. Physik
Neutrino opacities in the NJL model with color superconductivity — •Marco Hofmann[1], Alexander Haber[2], Liam Brodie[3], Mark Alford[3], Hosein Gholami[1], and Michael Buballa[1] — [1]Technische Universität Darmstadt, Germany — [2]University of Southampton, United Kingdom — [3]Washington University in St. Louis, Missouri, USA

Neutrino transport plays a critical role in the evolution of neutron star mergers and the cooling of neutron stars. In this work, the quark core in a hybrid star is modeled with a three-flavor NJL-type model that allows for color-superconductivity (arXiv:2408.06704). We calculate the direct Urca neutrino opacities of quark matter in the unpaired and in the two-flavor superconducting (2SC) phase. At low temperatures, the contribution of the gapped quarks can be neglected and we show how the self-consistently calculated quark masses determine the density-window in which the charged-current direct Urca process is kinematically allowed. While neutrino absorption by down quarks is kinematically forbidden at zero temperature, the process with strange quarks is kinematically allowed.