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Effective mass of a nucleus immersed in superfluid neutrons in the inner crust of a neutron star

Astronomical observations of neutron stars provide data on the kilometer scale, while the nuclear interaction, fundamental for neutron stars, works on the femtometer scale. To describe physical processes across so many orders of magnitude, one needs effective models. The inner crust of a neutron star is a complex system, where a lattice of nuclei strongly interacts with superfluid neutrons. In some situations one can neglect neutron and proton degrees of freedom and capture the essential physical phenomena by parametrizing nuclei with their effective mass, which emerges from the interaction with the background neutrons. We developed the *W-BSk Toolkit* [1], a general-purpose tool that uses time-dependent density functional theory to perform three-dimensional simulations of the inner crust without any geometric constraints. We use generalized Skyrme nuclear energy-density functionals of the Brussels-Montreal family. We study the nonequilibrium dynamics of a nucleus in different layers of the neutron star, which allows us to calculate the effective mass using the microscopic approach. Moreover, we identify, above a threshold velocity, three distinct mechanisms of energy dissipation: phonon emission, Cooper pair breaking, and vortex ring creation. The last mechanism is particularly interesting in the context of a microscopic source of glitches - sudden spin-ups of neutron stars.

[1] D. Pęcak, A. Zdanowicz, N. Chamel, P. Magierski, and G. Wlazłowski
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Author: Dr PĘCAK, Daniel (Institute of Physics, Polish Academy of Sciences)

Co-authors: ZDANOWICZ, Agata (Warsaw University of Technology); Prof. WLAZŁOWSKI, Gabriel (Warsaw University of Technology); CHAMEL, Nicolas (Université Libre de Bruxelles); MAGIERSKI, Piotr (Warsaw University of Technology)

Presenter: Dr PĘCAK, Daniel (Institute of Physics, Polish Academy of Sciences)

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