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Structures and properties of nuclear matter at the first-order phase transitions

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Abstract: A series of regular structures called "pasta" is expected at the first order phase transition of systems with charged multi chemical components. As an example, we study low-density nuclear matter in the crust region of neutron stars. We employ a relativistic mean-field model with Thomas-Fermi approximation. The calculation is done in a fully three-dimensional (3D) geometry [1] and we avoid a usage of Wigner-Seitz approximation which is very often used to reduce the computational cost.
We show that nuclear droplets form a body-centered-cubic (bcc) lattice at lower densities. With increasing density, it changes to a face-centered-cubic (fcc) lattice [2] before nuclear shapes change from spherical droplets to cylindrical rods. This is against the prediction of the conventional studies only with the bcc lattice which minimizes the Coulomb energy. Then we discuss the mechanical strength of such matter, by calculating the shear modulus directly obtained from the curvature of the energy versus shear deformation [3]. We also discuss the applicability of our 3D framework to two cases of high-density matter, i.e., kaon condensation and hadron-quark phase transition.

[1] M. Okamoto, et al, Phys. Lett. B 713, 284 (2012)
[2] M. Okamoto, et al, Phys. Rev. C 88, 025801 (2013)
[3] M. Okamoto, et al, in preparation