First-order phase transitions of nuclear matter and inhomogeneous structures of mixed phase

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We investigate inhomogeneous structures and properties of mixed phases during the first-order phase transitions: liquid-gas (LG) phase transition at slightly lower than the normal nuclear density ρ_0, meson condensation at several times of ρ_0, and hadron-quark (HQ) mixed phase at further higher density. Such phase transitions are expected in matter of neutron stars and play important roles on the equation of state (EOS) and consequently the stellar mass and radius, mechanical strength, and transport and thermal properties.

One of the characteristics of our approach is that we fully take into account the chemical equilibrium among constituents of coexisting two phases, which have been often omitted in the conventional studies using the Maxwell construction. We also take account of the geometries of mixed phases fully consistent with the Coulomb repulsion and the surface tension acting between coexisting phases. The resulting inhomogeneous mixed phases show regular structures consisting with spherical droplets, cylindrical rods, planar slabs, cylindrical tubes, and spherical bubbles, often collectively called "pasta". We show that the pasta structures appear repeatedly from the low-density LG mixed phase to the high-density QH mixed phase.