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Nuclear pasta phase in core-collapse supernova matter

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The core-collapse supernova phenomenon, one of the most explosive events in the Universe, presents a challenge to theoretical astrophysics. Of the large variety of forms of matter present in core-collapse supernova, we focus on the transitional region between homogeneous (uniform) and inhomogeneous (pasta) phases. We perform a three-dimensional, finite temperature Skyrme-Hartree-Fock + BCS (3D-SHF) study of the inhomogeneous nuclear matter, where we calculate self-consistently the nuclear pasta phase and determine the phase transition between pasta and uniform matter. As the nuclear matter properties depend on the effective nucleon-nucleon interaction in the 3D-SHF model, we employ four different parametrizations of the Skyrme interaction, SkM*, SLy4, NRAPR and SQMC700, and find subtle variations in the low density and high density transitions into and out of the pasta phase. One more stable pasta shape has been identified, in addition to the classic ones, on the grid of densities and temperatures used in this work. The data also indicate a discontinuity in the first derivatives of the free energy, which can be interpreted as a fingerprint of the first order transition between inhomogeneous and homogeneous supernova matter.

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