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Bridging Nuclear and Quark Matter: A Quantum van der Waals Approach to Quarkyonic Transition

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We extend the Quantum van der Waals description of nuclear matter at zero temperature to a high baryon density region by incorporating the continuous transition to quark matter in accordance with the recently proposed quarkyonic approach [1]. The nucleon-nucleon interaction parameters are fixed from the empirical properties of the nuclear ground state. The resulting equation of state exhibits the nuclear liquid-gas phase transition at $n_B \leq {}_0$ and undergoes a transition to quarkyonic matter at densities n_B $1.5{-}2\rho_0$ that are reachable in intermediate energy heavy-ion collisions. The transition is accompanied by a peak in the sound velocity. The results depend only mildly on the chosen excluded volume mechanism but do require the introduction of an infrared regulator Λ to avoid an acausal sound velocity. We also consider the recently proposed baryquark matter scenario for the realization of the Pauli exclusion principle, which yields a similar equation of state and turns out to be energetically favored in all the considered setups. The approach is extended to isospin asymmetric matter with applications to neutron star phenomenology [2] and can be generalized to finite temperatures relevant for binary neutron star mergers.

[1] R.V. Poberezhnyuk, H.Stoecker, V.Vovchenko, Phys.Rev.C 108 (2023) 4, 045202
[2] T.Moss, R.V. Poberezhnyuk, V.Vovchenko, in progress

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