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Confining density functional for QCD: heavy-ion collisions, neutron stars, mergers and supernovae

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We present a novel relativistic density functional approach for QCD matter, motivated by a nonlocal medium-screened confining interaction among quarks. The approach suggests a phenomenological confining mechanism equivalent to suppressing excitations of quark quasiparticles by their large self-energies already at the mean-field level. Chirally symmetric form of the functional provides spontaneous breaking and dynamical restoration of chiral symmetry of QCD and allows representing the approach as a chiral quark model with self-consistently derived medium-dependent couplings. Hadrons are systematically introduced to the approach within a generalized Beth-Uhlenbeck framework as color-singlet (anti)quark correlations. The approach explains why the abundances of hadrons produced in ultrarelativistic heavy-ion collisions (HIC) are well described by the hadron resonance gas model with a sudden chemical freeze-out at a well-defined hadronization temperature, defined by the chiral symmetry restoration driven Mott dissociation of hadrons, despite the fact that state of the art results of lattice QCD indicate a smooth chiral crossover. At high baryon densities, when repulsion and pairing among quarks play a significant role, the density functional is applied for modeling neutron stars (NS) and constructing equation of state for supernova explosions and mergers of NS. It is shown that color superconductivity drives trajectories of evolution of the QCD matter in these dynamical processes toward the high temperatures typical for HIC.

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