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# Quark Deconfinement in Neutron Stars and Their Mergers

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We outline the role that an early deconfinement phase transition from normal nuclear matter to a color superconducting quark-gluon plasma phase plays for the phenomenology of supernova explosions and binary neutron star mergers. To this end we develop a density functional approach to the equation of state (EoS) of quark matter with confinement and color superconductivity [1] and construct the transition to the EoS of the hadronic matter phase from vanishing to moderately high temperatures that will become accessible also in future terrestrial experiments with heavy-ion collisions. For the first time a phase transition construction is developed that allows for multiple critical points in the QCD phase diagram, including the possibility of a "crossover all over"[2].

We study the connection of such hybrid EoS with the mass-radius relation of cold compact stars, including the intriguing possibility of additional families, as a consequence of the presence of an early and strong phase transition. Special emphasis is devoted to the simultaneous fulfillment of the new constraint from the NICER mass and radius measurement on PSR J0740+6620 and the tidal deformability constraint from the binary neutron star merger event GW170817 which require the EoS to be soft at about twice saturation density and to stiffen at higher densities. Such a pattern is provided by an early and strong deconfinement transition [1]. We discuss whether the deconfinement signals remain intact which have recently been found in dynamical astrophysical scenarios, such as binary compact star mergers including the subsequent emission of gravitational waves [3] and supernova explosions of massive supergiant stars where neutrinos and gravitational waves play the role of messengers [4,5].

References:

[1] O. Ivanytskyi and D. Blaschke, "Density functional approach to quark matter with confinement and color superconductivity", Phys. Rev. D 105 (2022) 114042; arXiv:2204.03611.

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[4] T. Fischer et al., "Quark deconfinement as supernova explosion engine for massive blue supergiant stars" , Nature Astron. 2 (2018) 980.

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