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Dynamics of the QCD matter in heavy ion collisions and binary neutron star mergers

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For the first time, a single equation of state is used for dynamical simulations of binary neutron-star mergers and heavy-ion collisions [1]. That is done by employing the Chiral Mean Field (CMF) equation of state (EOS) [2] in self-consistent relativistic-hydrodynamic calculations for both systems. A direct comparison of the evolution of physical quantities like temperature, entropy, and baryon density in both systems allows to conclude that conditions created during these events are identical. A particular outcome of such an analysis is the universality of isentropes S/A=[1.8, 2.2] to describe bulk evolution of both binary neutron star mergers with $M_{\rm tot} = 2.6{-}2.8 M_\odot$ and heavy-ion collisions at the beam energies $E_{\rm lab} = [450, 600]$ A MeV. This provides concrete evidence that the physical conditions reached in binary neutron-star mergers can be studied in the present and future laboratory experiments.

Since the low energy collisions allow to study conditions of stellar neutron star mergers, it is important to understand up to which extent the QCD equation of state can be probed in the laboratory. The use of the hydrodynamic picture to describe experimental data at these collision energies is cumbersome since it strongly relies on the particlization routine. To tackle that, a procedure to incorporate any equation of state in the UrQMD microscopic transport model is introduced [3]. We employ the same CMF EOS in the transport simulations of heavy-ion collisions and compare them to the results of relativistic hydrodynamics. It is found that initial compression is similar if the same EOS is used in either dynamical model, but it also strongly depends on the actual EOS. These results indicate that the EOS can be unambiguously studied with observables that are sensitive to the initial compression phase in heavy-ion collisions.

[1] E. R. Most, A. Motornenko, J. Steinheimer, V. Dexheimer, M. Hanauske, L. Rezzolla and H. Stoecker, "Probing neutron-star matter in the lab: connecting binary mergers to heavy-ion collisions," [arXiv:2201.13150 [nucl-th]]

[2] A. Motornenko, J. Steinheimer, V. Vovchenko, S. Schramm and H. Stoecker, "Equation of state for hot QCD and compact stars from a mean field approach," [arXiv:1905.00866 [hep-ph]]

[3] M. O. Kuttan, A. Motornenko, J. Steinheimer, H. Stoecker, Y. Nara and M. Bleicher, "A Chiral Mean-Field Equation-of-State in UrQMD: Effects on the Heavy Ion Compression Stage," [arXiv:2201.01622 [nucl-th]]

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