Binary Hybrid Star Mergers and the Phase Diagram of Quantum Chromodynamics

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The detection of a gravitational wave (GW170817) from a binary compact star merger by the LIGO/VIRGO collaboration marked the beginning of a new era in observational astrophysics. With the use of the observed tidal deformations of the two compact stars the equation of state (EOS) of elementary matter could be severely constrained. The possible appearance of a transition from confined hadronic to deconfined quark matter (hadron-quark phase transition, HQPT), and the formation of regions of deconfined quark matter in the interior of a compact star merger product will be in the focus of this talk. The temperature and density structure of a neutron star merger product and the evolution of hot and dense matter inside the produced hypermassive/supramassive neutron star (HMNS/SMNS) advises an incorporation of a HQPT in the EOS [1, 2]. The occurrence of hot temperature regions and their spatial location is closely connected with the rotational properties of the HMNS/SMNS [3]. Additionally, the possibility of a viscousless superfluid quark phase might change the overall properties as viscous dissipation and energy transport can play a significant role in the survival time of the post-merger object [4]. Binary hybrid star mergers represent therefore optimal astrophysical laboratories to investigate the phase structure of quantum chromodynamics (QCD) and in addition with the observations from heavy-ion collisions will possibly provide a conclusive picture on the QCD phase structure at high density and temperature [5]. The results of numerical simulations of binary hybrid star mergers will be presented, where a strong HQPT has been implemented in the EOS. Especially, within an EOS that includes the possibility of a twin star behavior, the astrophysical observables of a HQPT might be observable by future detection of compact star merger events [6].

References

[1] M. Hanauske and L. Bovard. Neutron star mergers in the context of the hadron-quark phase transition. *Journal of Astrophysics and Astronomy*, 39:45, 2018.

[2] M. Hanauske, J. Steinheimer, A. Motornenko, V. Vovchenko, L. Bovard, E. Most, L. Papenfort, S. Schramm, and H. Stöcker. Neutron star mergers: Probing the eos of hot, dense matter by gravitational waves. *Particles*, 2(1):44–56, 2019.

[3] M. Hanauske, K. Takami, L. Bovard, L. Rezzolla, J. A. Font, F. Galeazzi, and H. Stöcker. Rotational properties of hypermassive neutron stars from binary mergers. *PRD*, 96(4):043004, 2017.

[4] Mark G. Alford, Luke Bovard, Matthias Hanauske, Luciano Rezzolla, and Kai Schwenzer. Viscous Dissipation and Heat Conduction in Binary Neutron-Star Mergers. *PRL*, 120:041101, 2018.

[5] M. Hanauske, J. Steinheimer, L. Bovard, A. Mukherjee, S. Schramm, K. Takami, J. Papenfort, N. Wechselberger, L. Rezzolla, and H. Stöcker. Concluding Remarks: Connecting Relativistic Heavy Ion Collisions and Neutron Star Mergers by the Equation of State of Dense Hadron- and Quark Matter as signalled by Gravitational Waves. In *Journal of Physics: Conference Series, Volume 878, Issue 1, article id. 012031 (2017).*, volume 878, page 012031, 2017.

[6] Gloria Montana, Laura Tolos, Matthias Hanauske, and Luciano Rezzolla. Constraining twin stars with GW170817. *ArXiv e-prints*, page arXiv:1811.10929, November 2018.