Spinodal instabilities of baryon-rich quark matter in heavy ion collisions

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Using the test-particle method to solve the transport equation derived from the Nambu-Jona-Lasino (NJL) model, we have studied how phase separation occurs in expanding quark matter like that in a heavy ion collision [1]. To test our method, we have first investigated the growth rates of unstable modes of quark matter in a static cubic box and found them to agree with the analytical results that were previously obtained using the linear response theory [2]. In this case, we have also studied the higher-order scaled density moments in the quark matter, which have values of one for a uniform density distribution or a distribution where the nonzero density regions all have same value, and they are found to increase with time and saturate at values significantly larger than one after the phase separation. The skewness of the quark number event-by-event distribution in a small subvolume of the system is also found to increase, but this feature disappears if the subvolume is large. For the expanding quark matter, two cases have been considered: one using a blast-wave model for the initial conditions and the other using initial conditions from a multiphase transport (AMPT) model [3]. In both cases, we have found that the expansion of the quark matter is slowed down by the presence of a first-order phase transition. Also, density clumps appear in the system and the momentum distribution of partons becomes anisotropic, which can be characterized by large scale density moments and nonvanishing anisotropic elliptic and quadrupolar flows, respectively. The large density fluctuations further lead to an enhancement in the dilepton yield. In the case with the AMPT initial conditions, the presence of a first-order phase transition also results in a narrower distribution of partons in rapidity. These effects of density fluctuations can be regarded as possible signals for a first-order phase transition that occurs in the baryon-rich quark matter formed in relativistic heavy ion collisions.

[1] F. Li and C.M. Ko, Phys. Rev. C **95**, 055203 (2017).
[2] F. Li and C.M. Ko, Phys. Rev. C **93**, 035205 (2016).
[3] Z.-W. Lin, C.M. Ko, B.-A. Li, B. Zhang, and S. Pal, Phys. Rev. C **72**, 064901 (2005).