Spinodal instability in baryon-rich quark matter

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The baryon-rich quark matter is expected to undergo a first-order phase transition at finite baryon density. Using the Polyakov Nambu-Jona-Lasinio (PNJL) model [1], which shows both the deconfinement and chiral phase transitions of quark matter at high temperature and density, we have studied the spinodal instability in a baryon-rich quark matter in the linear response theory [2]. Shown in Fig. 1 is the spinodal boundary in the temperature and density plane for different values of the wave number k of the unstable mode in the cases with (right window) and without (left window) a repulsive quark interaction. It is seen that the boundary of the spinodal region shrinks with increasing wave number, and for the same wave number, it is reduced by the repulsive quark vector interaction.

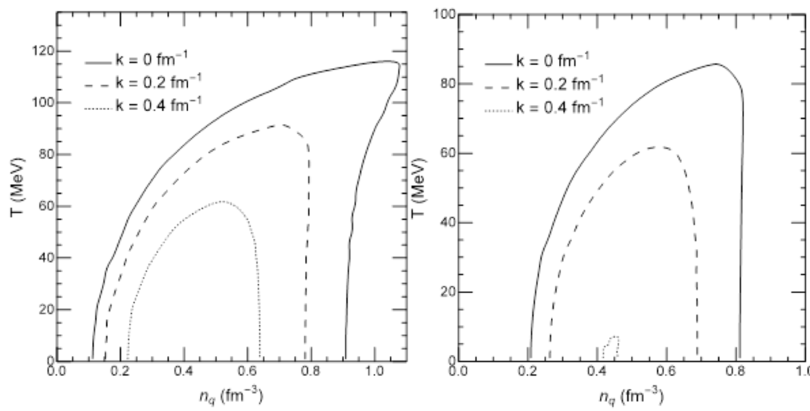

FIG 1. Spinodal boundaries in temperature and net quark density plane for different wave numbers with quark vector interaction $G_V = 0$ (left window) and $G_V = 0.2\ G_S$ (right window).

We have also calculated the growth rate of the unstable mode, which is given by the imaginary part of its dispersion relation, as a function of the wave number. For quark matter at temperature T = 70 MeV and net quark density nq = 0.7 fm-3, the growth rate of the unstable model in the absence of vector interaction first increases with the wave number and then decreases with the wave number after reaching a peak value of about 0.01 fm-1 at k ~ 0.15 fm-1. The growth rate is, however, significantly reduced after including the quark vector interaction, resulting in a suppression of the spinodal instability that is greater for unstable modes of shorter wavelength.

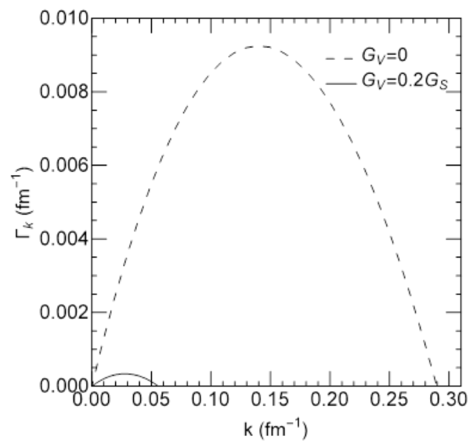

FIG 2. Growth rate of unstable modes in a quark matter of net quark density $n_q = 0.7$ fm^{-3} and at temperature T = 70 MeV for quark vector interactions $G_V = 0$ and $G_V = 0.2\ G_S$.

We have further derived a Boltzmann equation based on the Nambu-Jona-Lasinio (NJL) model. It is being solved [3] by the test particle method to study how density fluctuations grow in a baryon-rich quark matter and their effects on physical observables such as the net baryon number [4], rapidity distribution [5] event-by-event fluctuations, the anisotropic flows [6], and the dilepton yield.

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