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Interplay Between Quark-Antiquark and Diquark Condensates in Vacuum in a Two-Flavor Nambu-Jona-Lasinio Model

ZHOU Bang-Rong

College of Physical Sciences, Graduate School of the Chinese Academy of Sciences, Beijing 100049, China
CCAST (World Laboratory) P.O. Box 8730, Beijing 100080, China
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Abstract: By means of a relativistic effective potential, we analytically research competition between the quark-antiquark condensates $\langle\bar{q}q\rangle$ and the diquark condensates $\langle qq\rangle$ in vacuum in ground state of a two-flavor Nambu-Jona-Lasinio (NJL) model and obtain the G_S-H_S phase diagram, where G_S and H_S are the respective four-fermion coupling constants in scalar quark-antiquark channel and scalar color anti-triplet diquark channel. The results show that, in the chiral limit, there is only the pure $\langle\bar{q}q\rangle$ phase when $G_S/H_S>2/3$, and as G_S/H_S decreases to $2/3>G_S/H_S\geqslant 0$ one will first have a coexistence phase of the condensates $\langle\bar{q}q\rangle$ and $\langle qq\rangle$ and then a pure $\langle qq\rangle$ phase. In non-zero bare quark mass case, the critical value of G_S/H_S at which the pure $\langle\bar{q}q\rangle$ phase will transfer to the coexistence phase of the condensates $\langle\bar{q}q\rangle$ and $\langle qq\rangle$ will be less than 2/3. Our theoretical results, combined with present phenomenological fact that there is no diquark condensates in the vacuum of QCD, will also impose a real restriction to any given two-flavor NJL model which is intended to simulate QCD, i.e. in such model the resulting smallest ratio G_S/H_S after the Fierz transformations in the Hartree approximation must be larger than 2/3. A few phenomenological QCD-like NJL models are checked and analyzed.

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Key words: Nambu-Jona-Lasinio model, quark-antiquark condensates, diquark condensates, effective potential, chiral symmetry breaking, color-superconductivity

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