Precursor of Color Superconductivity

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We explore possible precursory phenomena of color superconductivity (CSC) above the critical temperature T_c in hot quark matter. We shall show that large fluctuations of the pair field of CSC exist even well above T_c. We discuss precursory phenomena due to the large fluctuations, which can be observed in heavy-ion collisions[1]. Thus the physics of CSC is related to heavy-ion collisions for the first time.

At low temperature and non-zero chemical potential, quark matter has a Fermi surface. If there is some attractive channel in the quark-quark interaction, the Fermi surface becomes unstable and quarks form Cooper pairs, which leads to superconductivity with a broken color-gauge symmetry, i.e., color superconductivity (CSC)[2].

So far, works concerning CSC in the literature have exclusively concentrated on the characteristics in the color-superconducting phase. Because the critical temperature T_c of CSC is rather low, it is difficult to create and observe this phase itself by heavy-ion collisions. Thus, it is natural that one considers that phenomena concerning CSC are most relevant to physics of neutron stars.

There is, however, a possibility to obtain the information on CSC through its fluctuations. Since QCD is a strong coupling theory, there may exist large fluctuations even well above the critical temperature. This is in contrast with ordinary superconductors of metals, in which fluctuations of Cooper pairs above T_c are significant only in the vicinity of the critical point. Therefore, the study of precursor phenomena may suggest promising signals for the creation of CSC in heavy-ion collisions, as may be performed in the planned new facility at GSI[3].

In this study, using the two-flavor and three-color Nambu-Jona-Lasinio model as a simplified effective model, say, of the ones with the instanton-induced interactions, we have investigated fluctuations of the pair field in hot quark matter in the Wigner phase above T_c using the linear response theory. We have found that there exist large fluctuations well above T_c. This implies a possibility to observe precursor phenomena of CSC in heavy-ion collisions. Furthermore, we confirm that such fluctuations form the so-called soft mode. Such a collective mode may affect the excess of the electro-magnetic as well as color conductivity above T_c, which is called "paraconductivity". We also argue that the spectral function of quarks in the normal phase in the vicinity of the critical point may show the so-called pseudogap due to the large fluctuations of the pair field, which is a famous precursor of high-T_c superconductivity.

References

[1] M. Kitazawa, T. Koide, T. Kunihiro and Y. Nemoto, Phys. Rev. **D** in press.
[2] For recent reviews, see K. Rajagopal and F. Wilczek, hep-ph/0011333;
M. Alford, hep-ph/0102047.
[3] See Proceedings of GSI workshop on its future facility:http://www.gsi.de/GSI-Future/.