Chromomagnetic Catalysis of Color Superconductivity

D. Ebert,[a] K. G. Klimenko, [b] and H. Toki[a]

[a] *Research Center for Nuclear Physics (RCNP), Ibaraki, Osaka 567-0047, Japan*
[b] *Institute for High Energy Physics, 142284 Protvino, Moscow region, Russia*

There exists the very exciting idea [1], that at high baryon densities a colored diquark condensate $< qq >$ might appear which signals color superconductivity (CSC) and spontaneous breakdown of color $SU_c(3)$ symmetry.

In the framework of the one-gluon exchange approximation in QCD the colored Cooper pair formation is predicted selfconsistently at extremely high values of the chemical potential ($\mu \geq 10^8$ MeV) which are not accessible in experiments (the typical densities inside the neutron stars or in the future heavy ion experiments correspond to $\mu \sim 500$ MeV). Recently, in the framework of QCD-motivated low energy effective theories (instanton induced four-fermion models, extended NJL models with $q\bar{q}$ and qq-interactions, etc) it was shown that CSC might exist in the region of moderate densities, and the diquark condensate might be as large as 100 MeV (see e.g. the review [2] and references therein). In the above mentioned effective theory approaches to CSC based on NJL models only the chiral condensate $< \bar{q}q >$ was taken into account leaving aside the gluon condensate (another nonperturbative characteristic of the QCD vacuum). On the other hand, at moderate densities, there might persist yet a rather large value of the gluon condensate which significantly might change the common picture of the CSC formation.

In the paper [3] the systematic investigation of the CSC in the framework of NJL models with $< qq >$ and $< \bar{q}q >$-condensates was started in the presence of some types of external chromomagnetic fields which simulate the gluon condensate. For simplicity, we constrained ourselves to a (2+1)-dimensional $SU(2)_L \times SU(2)_R$ chirally symmetric NJL model at vanishing temperature and chemical potential:

$$L = i\bar{q}\gamma^\mu(\partial_\mu + gA^a_\mu\frac{\lambda_a}{2})q + \frac{G_1}{6}[(\bar{q}q)^2 + (\bar{q}i\gamma^5\vec{\tau}q)^2] + \frac{G_2}{3}[i\bar{q}^C\varepsilon\epsilon^b\gamma^5 q][i\bar{q}\varepsilon\epsilon^b\gamma^5 q_C]. \qquad (1)$$

The external chromomagnetic field H (introduced by A_μ) was considered to belong to the algebra of the residual $SU_c(2)$ group, i.e. it might penetrate into the CSC phase. The results are the following.

If H acts on the CSC phase of the model (1), then the diquark condensate is a monotonically increasing function vs H, i.e. the gluon condensate stabilizes the CSC. Once the H is applied to the chiral phase, where $< qq >= 0$ and $< \bar{q}q >\neq 0$, the system passes to the mixed phase at some critical value $H_c \neq 0$. Finally, for sufficiently small values of $G_{1,2}$ and $H = 0$ there is a symmetric phase of the model, where $< qq >= 0$ and $< \bar{q}q >= 0$. However, including an arbitrary small external field H brings it to a CSC phase ($G_2 > G_1$) or to a chiral phase ($G_1 > G_2$). Hence, the process of diquark condensation might be catalyzed by external chromomagnetic fields.

References

[1] D. Bailin and A. Love, Phys. Rept. **107**,325 (1984).
[2] M. Alford, *Color superconducting quark matter*, hep-ph/0102047.
[3] D. Ebert, K.G. Klimenko and H. Toki, hep-ph/0011273, Phys.Rev. D (in print).