Magnetic properties of quark matter with the inhomogeneous chiral condensate

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We study the magnetic properties of quark matter in the inhomogeneous chiral phase, considering the " dual chiral density wave (DCDW) ", where both scalar and pseudoscalar condensates are spatially modulated. The response of quark matter to a tiny external magnetic field is investigated to show the existence of spontaneous magnetization in the DCDW phase.

In an external magnetic field, the energy spectrum of quarks becomes asymmetric about zero in the lowest Landau level, which is clearly related to chiral anomaly. We find that this spectral asymmetry also gives rise to the spontaneous magnetization, since a new term linearly proportional to the magnetic field is induced in the thermodynamic potential. However, this phenomenon includes not only the contribution of chiral anomaly but also one of valence quarks. Such spontaneous magnetization might be a candidate for the origin of the strong magnetic field in neutron stars; a simple estimate actually suggests $O(10^{16})$G.

We also show the peculiar behavior of magnetic susceptibility at the critical point: it never diverges unlike the usual ferromagnetic transition. Furthermore, considering the excitation around the ground state, we can see that the NG mode inherent in the ferromagnetic system; a magnon-like mode, does not exist there. These specific behaviors impliy there is no spontaneous symmetry breaking as in the usual spin alignment.