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Inhomogeneous phase during the chiral transition

Recently there have been many works about the inhomogeneous phases accompanying the chiral transition, which should have implications on relativistic heavy-ion collisions as well as compact-star phenomena [1].

Among them we here concentrate on the emergence and properties of a special one called dual-chiral-density wave (DCDW) state, which enjoys interesting features such as parity-violating phase, liquid-crystalline structure and spin-density wave [2]. In particular, the one-dimensional order is quasi-long-range-order in this case such that the correlation functions of scalar and pseudoscalar densities decay algebraically, as in the smectic liquid crystal[3]: fluctuations in the DCDW phase exhibit the heterogeneous dispersion relation.
The symmetry breaking pattern is also characteristic in this phase transition: U(1) subgroup of chiral symmetry and one-dimensional translational symmetry are broken at the same time, but is still invariant under the specific combination of them. So, Nambu-Goldstone modes (phasons) should exhibit a hybrid features of phonons and "pions". Moreover, magnetization spatially modulates to pretend a spin density wave, which may be related with the magnetic activity of compact stars.

After briefly introducing DCDW in the chiral limit and discussing its salient features, we elucidate the physical mechanism of its emergence; we emphasize differences from the usual Overhauser effect or the nesting effect of the Fermi surface.
Then we present a formalism to deform the original DCDW, to include the symmetry breaking effect [4]. Taking a variational method we show that the deformed DCDW can be described by a topological object: it is realized by embedding the chain of the sine-Gordon kinks in $1+1$ dimension into $1+3$ dimensional quark matter [5]. Thus we can generalize DCDW without losing the basic concepts.

Finally we briefly discuss the neutrino emission process by way of beta decay of quarks in the DCDW phase, as a definite example of implications of DCDW on compact-star phenomena [6].

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Primary author: Prof. TATSUMI, Toshitaka (Kyoto U.)

Presenter: Prof. TATSUMI, Toshitaka (Kyoto U.)

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