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QCD phase diagram with isospin and chiral imbalance and its dualities

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Recently it has been shown that in the large- N_c limit (N_c is the number of colors of quarks) there exist duality correspondences (symmetries) in the phase portrait, which are the symmetries of the thermodynamic potential and the phase structure itself. The first one is a duality between the chiral symmetry breaking and the charged pion condensation phenomena. And there are two other dualities that hold only for chiral symmetry breaking and charged pion condensation phenomena separately. For example, we have shown that charged pion condensation does not feel the difference between chiral and isospin imbalances of the medium. They were shown to exist in the matter with chiral imbalance that can be produced in compact stars or heavy ion collisions. One of the key conclusions of these studies is the fact that chiral imbalance generates charged pion condensation in dense baryonic/quark matter. It was shown that our results in particular cases are consistent with the simulation of lattice QCD, which is possible in these cases. Duality was used to show that there takes place catalysis of chiral symmetry breaking by chiral imbalance. It was also shown that chiral imbalance generates the phenomenon of charged pion condensation in dense baryonic/quark matter even in the case of charge neutral matter, which is interesting in the context of the astrophysics of neutron stars. It is known that chiral imbalance can occur in high energy experiments of the collision of heavy ions, due to temperature and sphaleron transitions. Our studies show that different types of chiral imbalance can occur in the cores of neutron stars or in heavy ion experiments, where large baryon densities can be reached, due to another phenomena - the so-called chiral separation and chiral vortical effects. Duality was shown to exist even in case of inhomogeneous condensates. This example shows that the duality is not just entertaining mathematical property but an instrument with very high predictivity power. The unified picture and full phase diagram of isospin imbalanced dense quark matter have been assembled. Acting on this diagram by a dual transformation, we obtained, in the framework of an approach with spatially inhomogeneous condensates and without any calculations, a full phase diagram of chirally asymmetric dense medium.

Continuing our studies of dualities, we noted that there are dualities in 2-color QCD that are connected with additional symmetry of QCD with two colors namely Pauli-Gursey symmetry. It has been also shown that found duality is a more fundamental and can be shown at the level of Lagrangian. It has been shown that duality is a property of real QCD. It is not bounded by large N_c approximation and exists in the cases of 2 and 3 and infinite number of colours.

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