Relativistic dissipative hydrodynamics with spontaneous symmetry breaking.

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Relativistic hydrodynamics has often been used as a starting point in the field of heavy ion collisions in order to reproduce single-particle spectra or multi-particle correlations (see [1] for example). However, the hot and dense hadronic phase created in such experiments is mainly constituted of pions and, until recently [2], no care has been taken on the fact that the breaking of the chiral symmetry can affect the theory of hydrodynamics itself [7]. Among all the applications of such a modification of the theory, two main directions emerge : first, it is highly wished to have a quantitative estimation of this effect when reproducing the experimental spectra [3] and, second it is important to complete the whole theory, that is, to include dissipation.
In hydrodynamic regime, relevant variables are those whose variations in space and time are slow and relaxation time becomes infinite in the long wavelength, small frequency limit. Such variables are of two kinds : densities of conserved quantities and Goldstone modes associated to continuous broken symmetry [4]. The prototype of such a theory which includes both types of hydrodynamic variables is the well-established theory of superfluidity associated to the breaking of $U(1)$ and developed many years ago by Landau [5] in the non-relativistic case (or [6] in the relativistic domain). Here, the example of the superfluidity will be used as a guideline in order to show explicitly how to include dissipation in hydrodynamic equations with a broken continuous symmetry. Then, I will generalize to the case of $SU(2)_L \times SU(2)_R$: starting from the equations of ideal hydrodynamics, I will introduce explicitely new transport coefficients associated to the chiral charge densities and Goldstone modes and discuss their physical meaning.

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