Hydrodynamics of Superfluid Bose Liquid as Hydrodynamics of One-component System

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Standard hydrodynamics of superfluid Bose liquid was elaborated by Landau and Khalatnikov. Domain of applicability of this theory is discussed in the literature[1]. Idea that the superfluid liquid consist of two subsystems with different properties is very attractive. However, this liquid consists of identical particles. Here hydrodynamics of the superfluid Bose liquid is formulated as a hydrodynamics of one-component liquid with additional variable (order parameter) which describes its broken symmetry. We introduce mass velocity by usual formula $\pi_n = \sigma \upsilon_n$ where π_n, σ are total momentum and mass density of the liquid. This relation and standard definition allow expressing of velocity of syperfluid υ_{sl} and normal υ_{nl} components by formulae $\upsilon_{sl} = \upsilon_l - \sigma_n \omega_l/\sigma$, $\upsilon_{nl} = \upsilon_l + \sigma_s \omega_l/\sigma$ ($\sigma \equiv \sigma_s + \sigma_n$, $\omega_l \equiv \upsilon_{nl} - \upsilon_{sl}$). Now we can write down all transformation laws (taken from usual hydrodynamics of one-component liquid) from laboratory reference system (RS) to local RS which moves with the velocity υ_l. Reversible contributions to energy and momentum fluxes in the last RS are given by expressions $q_l^0 = (s_0 T + \alpha\, \pi_0^2)\alpha\, \pi_{l0}$, $t_{lm}^0 = p_0 \delta_{lm} + \alpha\, \pi_{l0}\pi_{m0}$ ($\alpha \equiv \sigma_s/\sigma\sigma_n$). These formulas show that deviation of hydrodynamics of superfluid liquid from usual hydrodynamics of one-component liquid is defined by parameter α (π_{l0} is momentum in the RS of the superfluid component and is considered as the order parameter).

[1]S. J. Putterman, Superfluid hydrodynamics, New York, Elsevier (1974).