Ardizzone, L.; Gaeta, G.; Mongiovì, M. S.

Wave propagation in anisotropic turbulent superfluids. (English) Zbl 1285.82052


The paper is focused on the influence of an anisotropic vortex tangle on the propagation of first and second sounds. It is used the preliminary formulated hydrodynamic model of inhomogeneous superfluid turbulence. The model chooses as fundamental fields the mass density, velocity, energy density of He II and two extra variables, in order to include the specific properties of the fluid in consideration: the heat flux density and the averaged vortex line length per unit volume, $L$ (line density). First, the models of laminar and turbulent superfluids, derived by extended thermodynamics (ET), are briefly outlined – a macroscopic theory of non-equilibrium processes, which abandons the hypothesis of local equilibrium, and uses the dissipative fluxes as independent fields, besides the traditional variables. The non-standard one-fluid model of liquid He II for laminar flows, by using ET, chooses the mass density, velocity, absolute temperature and heat flux density as fundamental fields. In the hydrodynamic model of turbulent He II, by using ET, one adds the additional scalar variable (line density) to the fields chosen to describe laminar flows, in order to describe the presence of the turbulent vortex tangle. Then, the propagation of first and second sounds is studied and the influence of the presence of a non-isotropic vortex tangle on their velocities and attenuation coefficients is examined. The propagation of waves in a neighborhood of stationary solutions of quasi-linear systems of nine partial differential equations, obtained on the base of a production term in the evolution equation for the line density, formulated by using the Vinen’s expression, is studied considering the nine evolution equations. The speeds, attenuation coefficients and amplitudes of these waves are found in two cases of waves propagating in parallel and orthogonal directions to the heat flux. The modifications to the speed and the amplitude of these waves induced by the anisotropic vortex tangle are determined by using a perturbation method. It is shown that the presence of the quantized vortex couples first and second sounds and the attenuation of the second sound is proportional to the line density, $L$, in the case, when the wave propagates orthogonal to the heat flux. At the same time, this attenuation is proportional to the square root of $L$, when the wave propagates parallel to the heat flux.

Reviewer: I. A. Parinov (Rostov-na-Donu)

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82D50 Statistical mechanics of superfluids
76Y05 Quantum hydrodynamics and relativistic hydrodynamics

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References:


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