Quasi-linear Theory of Quantum Fermi Liquid Oscillations

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Abstract

Theory of the quantum liquid (isotope of helium He^3 at temperature ~1-2^0K) is due to L. Landau [1] in which L. Landau took into account only the weakly excited energy levels of the Fermi Liquid, lying fairly close to the ground state. In his theory Landau has shown that the undamped zero sound can exist in an almost ideal Fermi Liquid.

Quite recently, in the article [2] authors extend Landau's theory of Fermi Liquids by taking into account the de Broglie waves diffraction, and show ,that even in an ideal Fermi gas, when the interaction between atoms is absent, the dispersion equation of the zero sound preserves the form. To investigate the problem of existence of the zero sound in He^3 Liquid, authors [2] derived a novel quantum kinetic equation. Also authors [2] disclose a new branch of frequency spectrum due to the weak interaction.

In this report, we consider the case of many waves with different phase velocities. Such situation takes place in a weakly turbulent quantum liquid.

The quasi-linear theory describes the dynamics of the interaction between the resonance He^3 atoms and the waves. The quasi-linear theory is able to treat such processes when the energy of the oscillations is appreciably less than the degenerate Fermi energy, but is, at the same, very much greater than the thermal noise energy. The creation of the quasi-linear theory lies in the division of the particle distribution function into two parts: a rapidly oscillating part and a slowly varying part, and also in calculating the influence of the mean square of the oscillating part on the slowly varying part. It is found that the behavior of the slow part of the distribution function can be described by a diffusion equation in momentum space and the rate of damping or growth (instability) of the rapid oscillations is given by the linear theory equations in which the non-oscillating part of the distribution function varies slowly with time.

In this paper we used quasi-linear theory to derive diffusion equation in momentum space for particle distribution function and showed that due to de Broglie diffraction, diffusion equation maintains its form, when there is no interaction between He^3 isotopes. We also derived the solution for diffusion equation and calculated the mean energy, which depends on time linearly and increases due to diffusion in momentum space.

[1] L. D. Landau, *Zh. Eksp. Theor. Fiz.* 30, 1058 (1956); ibid. 32, 59 (1957); ibid. 35, 97 (1958).

[2] N. L. Tsintsadze and L. N. Tsintsadze*, Europhys. Lett*. 88, 35001 (2009); in: *From Leonardo to ITER*: *Nonlinear and Coherence Aspects*, Jan Weiland (ed.), AIP Proc. No. CP1177 AIP, New York (2009); *e-print arXiv: physics/0903.5368v1*.