Dark solitons: a model of impurity-phonon interactions in quantum liquids

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Understanding of interactions between quantum liquids and impurities is important for studying superfluid flow in disordered media in 1d. Impurities create nonlinear disturbances in the quantum liquid with a complicated dynamics. For low enough temperatures and velocities of the liquid the description can be simplified and leads to an universal Hamiltonian describing interactions of the dressed impurities with long wavelength phonons. The phenomenological parameters of this Hamiltonian can be determined semiclassically in the case of weak interactions. In this talk we review this method and apply it to study dissipative dynamics of dark solitons, which may be regarded as mobile impurities. Our main findings are as follows.

Unless protected by the exact integrability, solitons are subject to dissipative forces, originating from a thermally fluctuating background. At low enough temperatures T background fluctuations (phonons) should be considered as being quantised. Since the soliton velocity V is always smaller than the speed of sound c, emission of a single phonon is forbidden by the energy and momentum conservation, *i.e.* by Landau criterion. The leading allowed process is the Raman two-phonon scattering, where one thermal phonon is absorbed and another one reemitted. This enables us to calculate finite lifetime of the solitons $\tau \sim T^{-4}$. We show that the prefactor in the expression for the life-time depends crucially on integrability properties of the quantum liquid model. We also find that the coherent nature of the quantum fluctuations leads to enhanced mutual friction of solitons due to the superradiation of phonons.

Our results are of relevance to current experiments with ultracold atoms, while the approach may be extended to solitons in other media.

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[1] D. M. Gangardt and A. Kamenev, Phys. Rev. Lett. **102**, 070402 2009.
[2] D. M. Gangardt and A. Kamenev, accepted for publication in Phys. Rev. Lett.