A Massive Quasiparticle in a Phonon Gas

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We consider in dimension 3 a very low-temperature homogeneous superfluid exhibiting two types of excitations, (i) gapless acoustic phonons of linear dispersion relation at low wavenumber, and (ii) gapped γ quasiparticles of quadratic (massive) dispersion relation in the vicinity of its extrema. Recent work [1,2], extending the historical study of Landau and Khalatnikov [3] on the phonon-roton interaction in liquid helium-4, has explicitly determined the scattering amplitude of a thermal phonon on a quasiparticle at rest to leading order in temperature. We generalize this calculation to the case of a quasiparticle of arbitrary subsonic group velocity [4], with a rigorous construction of the S-matrix between exact asymptotic states, taking into account the incessant phonon-phonon and phonon-γ interaction, which dresses up the incident or emerging phonon and quasiparticle with virtual phonons; this sheds new physical light on the Feynman diagrams of phonon-γ scattering. In the whole parameter space (wave number, interaction strength, *etc.*) where the γ quasiparticle is energetically stable with respect to the emission of phonons of arbitrary wave vectors, we can then characterize the erratic motion it performs in the superfluid as a result of its incessant collisions with the thermal phonons, through the average force and the longitudinal and transverse diffusion coefficients involved in a Fokker-Planck equation, and then, at long times when the quasiparticle has thermalized, through the spatial diffusion coefficient.

References

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