Phonon Damping in a 2D Superfluid: Insufficiency of Fermi's Golden Rule at Low Temperature

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In three dimensions, it is generally accepted that the phonon gas of a superfluid always enters a weak coupling regime at sufficiently low temperatures, regardless of the strength of the interactions between the constituent particles of the superfluid. Thus, in this limit, one should always be able to calculate the damping rate of thermal phonons by applying Fermi's golden rule to the cubic phonon-phonon coupling Hamiltonian H_3 (at least in the collisionless regime). With the many-body Green function method, we predict, for a convex acoustic branch and by simple power counting, that this is not true in two dimensions. We quantitatively confirm this prediction by classical phonon field simulations and by a nonperturbative theory in H_3. For a weakly interacting fluid, we predict at long wavelengths a damping rate about three times lower than that of the golden rule.

References

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