Modeling Kelvin Wave Cascades in Superfluid Helium

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We study two different types of simplified models for Kelvin wave turbulence on quantized vortex lines in superfluids near zero temperature. Our first model is obtained from a truncated expansion of the Local Induction Approximation (Truncated-LIA) and it is shown to possess the same scalings and the essential behaviour as the full Biot-Savart model, being much simpler than the latter and, therefore, more amenable to theoretical and numerical investigations. The Truncated-LIA model supports six-wave interactions and dual cascades, which are clearly demonstrated via the direct numerical simulation of this model in the present paper. In particular, our simulations confirm presence of the weak turbulence regime and the theoretically predicted spectra for the direct energy cascade and the inverse wave action cascade. The second type of model we study, the Differential Approximation Model (DAM), takes a further drastic simplification by assuming locality of interactions in k-space via a differential closure that preserves the main scalings of the Kelvin wave dynamics. DAMs are even more amenable to study and they form a useful tool by providing simple analytical solutions in the cases when extra physical effects are present, e.g. forcing by reconnections, friction dissipation and phonon radiation. We study these models numerically and test their theoretical predictions, in particular the formation of the stationary spectra, and the closeness of the numerics for the higher-order DAM to the analytical predictions for the lower-order DAM .

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