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Modeling Multi-Phase Flow using Fluctuating Hydrodynamics

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Incorporating thermal fluctuations in continuum Navier-Stokes equations requires the development of numerical methods that solve the complex stochastic partial differential equations of fluctuating hydrodynamics. The situation becomes more complex when more than one fluid phase is involved as in a liquid-vapor system. We describe a stochastic method of lines discretization of the fully compressible Landau-Lifshitz-Navier-Stokes equations with the van der Waals equation of state. The diffuse interface method is used to model the order parameter (density) across the interface with the surface tension effects giving rise to Korteweg type stresses in the momentum and energy equations. The numerical scheme is validated by comparison of measured structure factors and capillary wave spectra with equilibrium theory. We also present several non-equilibrium examples to illustrate the capability of the algorithm to model multi-phase fluid phenomena in a neighborhood of the critical point. These examples include a study of the impact of fluctuations on the spinodal decomposition following a rapid quench, as well as the piston effect in a cavity with supercooled walls. The conclusion in both cases is that thermal fluctuations affect the size and growth of the domains in off-critical quenches.

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