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Analysis of Explicit Algorithms for Fluctuating Hydrodynamics[1]

A.C. DONEV, LBNL, E. VANDEN-EIJNDEN, Courant Institute, NYU, A. GARCIA, Dept. Physics & Astronomy, SJSU, J. BELL, LBNL — We describe the development and analysis of finite-volume methods for the Landau-Lifshitz Navier-Stokes (LLNS) equations and related stochastic partial differential equations in fluid dynamics. The LLNS equations incorporate thermal fluctuations into macroscopic hydrodynamics by the addition of white-noise fluxes whose magnitudes are set by a fluctuation-dissipation relation. We introduce a systematic approach based on studying discrete equilibrium structure factors for a broad class of explicit linear finite-volume schemes. This new approach provides a better characterization of the accuracy of a spatio-temporal discretization as a function of wavenumber and frequency, allowing us to distinguish between behavior at long wavelengths, where accuracy is a prime concern, and short wavelengths, where stability concerns are of greater importance. We use this analysis to develop a specialized third-order Runge Kutta scheme that minimizes the temporal integration error in the discrete structure factor at long wavelengths for the one-dimensional linearized LLNS equations. Together with a novel random-direction method for evaluating the stochastic fluxes in dimension larger than one, our improved temporal integrator yields a scheme for the three-dimensional equations that satisfies a discrete fluctuation-dissipation balance for small time steps and is also sufficiently accurate even for time steps close to the stability limit.

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Aleksandar Donev
Lawrence Berkeley National Laboratory

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