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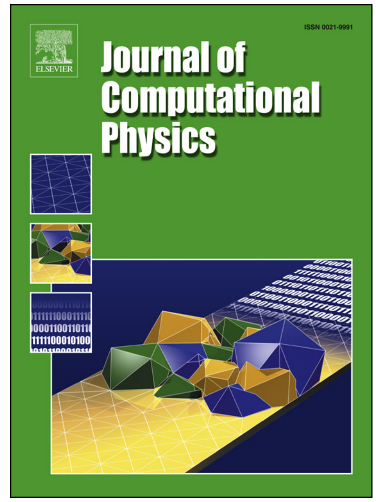

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An Arbitrary-Order, Fully Implicit, Hybrid Kinetic Solver for Linear Radiative Transport Using Integral Deferred Correction[☆]

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Abstract

In this work, we describe the implementation of an arbitrarily high-order hybrid solver for linear, kinetic, radiative transport equations. The hybrid method is derived from a splitting of the radiative flux into free-streaming and collisional components to which high- and low-resolution discrete ordinates methods are applied, respectively. Arbitrarily high orders of accuracy with respect to time and space are attained by combining an integral deferred correction (IDC) time integration scheme constructed with implicit Euler substepping on Radau II (right biased) nodes with an upwind discontinuous Galerkin (DG) spatial discretization on uniform Cartesian meshes. Numerical experiments are used to demonstrate that the aforementioned IDC methods can be constructed such that they are unconditionally stable (L-stable) to within machine precision. Asymptotic analysis is used to show that such IDC methods also preserve the diffusion limit of the underlying transport equation on the semi-discrete level, in the sense that the semi-discrete transport system under an implicit IDC discretization recovers the same IDC discretization of the limiting diffusion equation. Convergence results in one spatial dimension are provided, and it is found that while the hybrid method exhibits convergence stagnation and order reduction in certain scenarios, the overall accuracy of the hybrid approximation is comparable to a standard discrete ordinates approximation in many cases. Numerical results for two test problems in two spatial dimensions are given to compare the computational efficiency of the hybrid method against a standard discrete ordinates method, and to compare the efficiency of space-time discretizations of different orders of accuracy. The results indicate that a properly chosen hybrid discrete ordinates method can be more efficient than a standard discrete ordinates method by a factor of between 2 and 8 when IDC timestepping methods are used. Further, among the first-, third-, and fifth-order space-time discretizations considered here, the first-order method is the least efficient and the third-order method is the most efficient.

Keywords: hybrid methods, kinetic equations, integral deferred correction, fully implicit methods, high-order accuracy

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