Modern implicit algorithms for multiscale kinetic plasma simulation

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High-fidelity kinetic plasma models are exceedingly multiscale and of difficult numerical solution, continuously challenging the numerical modeler to develop faster, more clever algorithms and formulations on bleeding-edge architectures. For decades, physicists have resorted to the development of reduced models to push the state of the art in our understanding of plasma behavior. This has naturally led to hierarchical (nested) models, with transport and ideal MHD at the top of the hierarchy, to resistive and extended MHD, to gyrokinetic and fully kinetic models at the bottom. For many years, these models have been used in isolation, to address targeted temporal scales and physics phenomena. However, owing in part to the promise of exascale computing, in part to the advances in nonlinear solver technology, and in part to the maturing of our algorithmic perspective, it is now becoming possible to solve these hierarchical descriptions in a tightly coupled manner using implicit methods [1] while enforcing key conservation properties (e.g., mass, momentum, and energy) that improve long-term accuracy. These hierarchical algorithms couple these descriptions across scales, targeting discretizations (e.g., Lagrangian vs. Eulerian) and architecture optimizations at each level, while leveraging reduced models for algorithmic acceleration. In this talk, I will discuss recent progress in the development of conservative implicit solvers for collisionless [2-6] and collisional [7-11] kinetic models and their applications, with emphasis on their efficiency and accuracy properties.

References

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