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STRUCTURE-PRESERVING AND ASYMPTOTIC-PRESERVING PARTICLE METHODS FOR PLASMA SIMULATION

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ABSTRACT

Many natural (e.g., the Earth's magnetosphere) and laboratory (e.g., fusion) plasmas feature non-thermal-equilibrium (e.g., kinetic) features that need to be properly captured for physics fidelity, and which challenge their numerical simulation. First-principles descriptions of such plasmas demand a six-dimensional phase-space representation plus time, coupling the Vlasov-Fokker-Planck and Maxwell's equations, which is prohibitive to solve on a mesh for many engineering applications due to the curse of dimensionality. The challenges worsen for magnetized plasma systems, as the magnetic field introduces gyromotion timescales that may need to be either respected for accuracy or asymptotically removed from the formulation, losing generality. Particle methods offer a way to simulate these systems while managing the curse of dimensionality, but the lack of strict conservation properties (e.g., momentum and/or energy) and the need to respect temporal and spatial stability and/or accuracy constraints have challenged their use for engineering plasma applications, even with the largest supercomputers on Earth. The last decade has witnessed a paradigm shift in particle plasma simulation with the development of structure-preserving (SP) and/or asymptotic-preserving (AP) particle schemes for both collisional (e.g., [1]) and collisionless plasmas of arbitrary magnetization (e.g., [2]). In this Invited Session, we will gather world experts in the field to present the latest developments on these timely topics.

REFERENCES

[1] Bailo, Rafael, José A. Carrillo, and Jingwei Hu. "The collisional particle-in-cell method for the Vlasov-Maxwell-Landau equations." *arXiv preprint arXiv:2401.01689* (2024), to appear in J. Plasma Physics.

[2] Chen, Guangye, and Luis Chacón. "An implicit, conservative and asymptotic-preserving electrostatic particle-in-cell algorithm for arbitrarily magnetized plasmas in uniform magnetic fields." *Journal of Computational Physics* 487 (2023): 112160.