Contribution ID: **9** Type: **not specified**

A IMEX-based spectral scheme with adaptive time-stepping for the Vlasov-Poisson system in the quasi-neutral limit

Wednesday, 11 February 2026 17:00 (25 minutes)

The choice of the time step is important not only for stability, but also for efficiency and consistency with the equations under consideration. In the context of kinetic equations, these aspects are particularly critical. On the one hand, efficiency must be optimized because of the high dimensionality of phase space, which may range from 2 to 6 depending on the problem, leading to a very large computational cost. On the other hand, the simulation of models, especially in Plasma Physics, often involves very fast dynamics that require an appropriate time discretization in order to be accurately resolved. The aim of this talk is to present recent results on time-step selection strategies applied to a numerical scheme for the Vlasov–Poisson equation in the quasi-neutral limit. The scheme is based on a Hermite spectral decomposition in velocity and a finite-difference discretization in space, and was originally proposed in 2025 by Blaustein, Dimarco, Filbet, and Vignal. It relies on a fully implicit, L-stable DIRK time discretization, yielding an Asymptotic-Preserving method in the quasi-neutral limit, at the expense of a significant computational cost per time step. A key issue is that, although the L-stable scheme can capture the oscillating behavior in time of the Vlasov–Poisson system (particularly those of the electric field and current density) in the asymptotic regime, its dissipative nature may eventually damp these oscillations if the time step is not properly chosen. In this work, we instead adopt an IMEX approach, treating the nonlinear part implicitly and the linear part explicitly. This substantially improves the efficiency while maintaining stability, although the Asymptotic-Preserving property is lost. Combined with this semi-implicit treatment, we aim to exploit the accuracy control performed by the time-step selection technique and use it as main ingredient for recovering the fast and ample oscillations in time.

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