



THE HONG KONG UNIVERSITY OF SCIENCE & TECHNOLOGY

Department of Mathematics

SEMINAR ON APPLIED MATHEMATICS

**Sampling-Based Adaptive Rank Integrators for
Multi-scale Kinetic Models**

By

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Abstract

In this talk, we introduce a sampling-based semi-Lagrangian adaptive rank (SLAR) method, which leverages a cross approximation strategy—also known as CUR or pseudo-skeleton decomposition—to efficiently represent low-rank structures in kinetic solutions. The method dynamically adapts the rank of the solution while ensuring numerical stability through singular value truncation and mass-conservative projections. By combining the advantages of semi-Lagrangian integration with low-rank approximations, SLAR enables significantly larger time steps compared to conventional methods and is extended to nonlinear systems such as the Vlasov-Poisson equations using a Runge-Kutta exponential integrator.

Building on this framework, we further develop the SLAR method for the multi-scale BGK equation, introducing an asymptotically accurate approach that eliminates the need for low-rank decompositions of the local Maxwellian in the collision operator. To enforce conservation of mass, momentum, and energy, we propose a novel locally macroscopic conservative (LoMaC) technique, which discretizes the macroscopic system using high-order DIRK methods. Additionally, a dynamic closure strategy is employed to self-consistently adjust macroscopic moments, enabling robust simulations across both kinetic and hydrodynamic regimes, even in the presence of shocks and discontinuities.

We validate our method through extensive benchmark tests on linear advection, onto 3D3V nonlinear Vlasov-Poisson, and multi-scale kinetic problems, demonstrating its accuracy, stability, and computational efficiency. The Sampling-Based Adaptive Rank framework offers a promising pathway for overcoming the curse of dimensionality in high-dimensional multi-scale kinetic problems.

Date : 16 June 2026 (Tuesday)

Time : 2:00p.m.-3:00p.m.

Venue : Room 4504 (Lift 25 & 26)

All are Welcome!