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High-order Numerical Methods for Plasma Simulations on Large-scale High-Performance Computing Architectures

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Modeling diverse physical processes using mathematical algorithms has become a successful tool in modern science and engineering. The underlying mathematical models are carefully designed to perform large-scale computer simulations that involve disparate scales of space and time. Such complexities often arise when incorporating various multi-physics components that can be represented by classes of partial differential equations.

In the first part, I will discuss key issues in seeking computational solutions on large-scale high-performance Computing (HPC) architectures, and the need for using high-order numerical algorithms on HPC. I describe mathematical algorithms with special attention to two numerical approaches: first, the traditional formulations based on high-order polynomials; second, a new innovative exponentially converging formulation based on Gaussian Process Modeling. Moreover, I will show the importance of fast convergent, high-order accurate numerical methods and how they are crucial for future high-performance exascale computing architectures.

In the second part, I will present laboratory astrophysics scientific simulations using the numerical algorithms introduced in the first part. They include large-scale computer simulations of astrophysics and high-energy-density plasma physics, with special emphasis on laser-driven shock experiments to shed lights on the processes behind magnetic field generation and amplification.

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