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Endowing kinetic transport equations using a BGK collision term with additional physics

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We consider kinetic equations of the Boltzmann equation type. We simplify the detailed collision term of the Boltzmann equations by a so called BGK term. This leads to a large saving in computational effort.

The computational efficiency of kinetic BGK models compared to Boltzmann models comes at the price of the simplification of physics. We have been engaged in an endeavor of putting some physics back into BGK models. A project in this spirit arose in the context of simulating internal confinement fusion: in plasma the collision frequency varies with the microscopic velocity, what would that do to BGK models?

Fundamental issues had to be surmounted. In this case the equilibrium no longer is a Maxwellian. This warranted a new numerical approach, as explained in the paper [1].

A nice outcome of this paper is that there are physical regimes that occur in inertial confinement fusion, where this modeling makes a difference, compared to standard BGK models.

Using a two-species version of our new BGK model (an extension of [2]), we simulated the dynamics of two counterstreaming beams of light hydrogen-ions moving to the left and heavy helium-ions moving to the right. In the simulation with the velocity dependent collision frequency model the helium penetrates deeper into the right compared to the simulation with constant collision frequency. Our model reproduces physics much more accurately.

This is joint work with Jeffrey Haack, Cory Hauck, Christian Klingenberg, Marlies Pirner and Sandra Warnecke.

References

[1] Jeffrey Haack, Cory Hauck, Christian Klingenberg, Marlies Pirner, Sandra Warnecke: "Numerical schemes for a multi-species BGK model with velocity-dependent collision frequency", *submitted, available on arXiv* (2022)

[2] Christian Klingenberg, Marlies Pirner, Gabriella Puppo: "A consistent kinetic model for a two-component mixture with an application to plasma", *Kinetic and Related Models* Vol. 10, No. 2, pp. 445-465 (2017)

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