A Grad closure for low-temperature plasmas: derivation of the equations, numerical methods and validation with experiments

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Standalone fluid-based models usually fail to fully represent the physics of low-temperature plasmas in weakly-collisional regimes where the local thermodynamic equilibrium is no longer valid and kinetic effects are important. In this talk, we will derive a velocity-moment plasma model from the kinetic equation by means of Grad's method that accounts for a multi-component reacting mixture in chemical and thermal non-equilibrium with the effect of an electromagnetic field [1]. The model considers the evolution of mass, momentum, energy, heat flux vector and the contracted fourth moment balance equations for each plasma species. By doing this, the excess kurtosis of the electron population at high energies, typical in low-temperature plasmas, is self-consistently captured by the model.
We will explain the derivation of the collisional terms for both elastic and inelastic collisions by using the full Boltzmann operator as opposed to a simplified BGK operator. Different asymptotic limits of these equations with respect to the collisionality, quasi-neutrality, and electron inertia will be discussed [2]. Finally, we propose asymptotic-preserving discretizations in order to avoid severe time-step restrictions due to the resolution of the small scales under some regimes of interest. Comparison of the plasma moment model with kinetic simulations and experimental results will be discussed in this talk.

[1] A. Alvarez Laguna, N. Ozak, A. Lani, H. Deconinck, S. Poedts. *Fully-implicit finite volume method for the ideal two-fluid plasma model.* Computer Physics Communications, **231**, 31–44, 2018.

[2] A. Alvarez Laguna, T. Pichard, T. Magin, P. Chabert, A. Bourdon, M. Massot. *An asymptotic preserving well-balanced scheme for the isothermal fluid equations in low-temperature plasmas at low-pressure.* Journal of Computational Physics, **419**, 109634, 2020.

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