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Diffusive Boltzmann equation, its fluid dynamics, Couette flow and Knudsen layers

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***Highlights (for review)**

We show that the dynamics of a realistic gas, described by a deterministic interaction process, cannot be directly reduced to the Boltzmann equation (the Vlasov equation results instead).

We introduce a new, random multimolecular process ("random gas") which leads directly to the Boltzmann equation.

We parameterize the difference between the realistic gas and the random gas via a multiscale homogenization formalism, which equips the Boltzmann equation with an additional spatial diffusion term.

We subsequently obtain the corresponding diffusive closures of the fluid dynamics from the diffusive Boltzmann equation; in particular, the Grad closure is diffusive and thus well posed under the Dirichlet boundary conditions.

We study the Couette flow, where the Knudsen boundary layers are captured with good accuracy and the Grad closure additionally captures the parallel heat flux. We verify the solutions of the fluid dynamics closures against the Direct Simulation Monte Carlo method, for two gases, argon (monatomic) and nitrogen (diatomic).