Universidad Carlos III de Madrid

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A new perspective on the moment closure problem in radiative transfer

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Abstract

Radiative transfer can be modeled by a kinetic equation that describes the evolution of the particle intensity function in a high dimensional phase space of (at least) time, position, and angle of flight. While a direct simulation of the mesoscopic kinetic equation is possible, many computational scientists prefer a description by macroscopic equations. An expansion in the angular variable yields an equivalent system of infinitely many macroscopic moment equations. The fundamental question how to best truncate this system is the moment closure problem. Various closure strategies exist. These are typically based on an asymptotic analysis or assume higher moments be quasi-stationary.

We present an alternative approach to derive moment closures, based on the Mori-Zwanzig formalism of irreversible statistical mechanics. The influence of the truncated moments on the revolved moments is modeled by a memory term. Suitable approximations to this memory term allow us to re-derive existing closures, such as PN, SPN, and diffusion correction closures. In addition, new closures can be derived. We propose a crescendo-diffusion closure, which improves classical diffusion closures at no extra cost, as well as a new class of parabolic-type closures.

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