An asymptotic preserving and well-balanced scheme for the M1 model for radiative transfer

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The problem of radiative transfer describes the interaction between light and matter, therefore it appears in many physical situations, such as astrophysical systems, laser matter interactions, or atmospheric physics [1]. Instead of solving a complex equation in a seven dimensional space, one can use a moment model by averaging over the direction of propagation to follow the radiative energy, flux, pressure, etc in a five dimensional space. By using a closure relation expressing the radiative pressure as a function of radiative energy and flux, one can derive the M_1 model [2, 3] that is able to accurately capture the two main regime in radiative transfer: optically thin medium in which photons are free streaming and the optically thick medium in which photons are constantly interacting and obey a diffusion equation in the asymptotic limit [4].

At the discrete level, two major difficulties relating to the M_1 model come from the asymptotic behaviour and the capture of constant flux steady state that are difficult to capture by standard finite volume approaches. To deal with these issues, we propose an asymptotic preserving and well-balanced scheme. The Riemann fluxes on the radiative energy equations are corrected to get the asymptotic preserving property, and the whole scheme is also adapted to get the well-balanced property for constant flux steady state with variable opacities. We present also first tests showing these properties of the proposed numerical scheme.

A time explicit scheme would be limited by the speed of light, therefore a time implicit solver is used. Linear systems are solved using the library Trilinos. The implementation is done using the code ARK developed in [5] in order to achieve high performance computing and portability across different architectures (e.g. multi-core, many-core, GP-GPU).

Références

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