New computational method for multigroup radiative hydrodynamics using Artificial Intelligence: Optimisation of the Eddington factor calculation

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Radiative hydrodynamics models the coupling between the dynamics of a hypersonic hot plasma and the radiation it produces or external radiation. Almost every numerical codes use simplified models, that are in most cases either limited or wrong. To accurately model the photon transport the HADES 2D code was specifically developed [2, 3, 4]. Such a code is indispensable for studying astrophysical objects, in which optically intermediate regions are still poorly modeled, yet commonly encountered within such phenomena.

This code couples the hydrodynamics with the M1-multigroup model for radiation transfer [1], to accurately represent the spectral behavior of light, involving the partitioning of the electromagnetic spectrum into groups [5]. Nevertheless, simulating radiative hydrodynamics flows remains highly time-consuming, constraining our capacity to conduct comprehensive numerical studies within this field.

The most expensive part of the M1-multigroup simulations is the calculation of the closure relation, relating the radiative pressure to the radiative energy and the radiative flux, via the Eddington factor. This is due to the lack of an analytical solution. Consequently, two methods exist:

- one accurate yet costly, relying on expensive search algorithms implemented in HADES [4],
- another quicker but incorrect, utilizing the analytical grey case closure relation for each group, implemented in HERACLES [6].

To mitigate these challenges, we've pioneered an inventive approach intertwining neural networks with simplified models. This innovative method dramatically reduces the computation time, while maintaining an acceptable precision, revolutionizing the efficiency of these calculations within M1-multigroup simulations.

To affirm the efficiency of our approach, we conducted validation simulations, beginning with the renowned benchmark simulation of a 1D radiative shock, wherein we used up to five groups. Additionally, we undertook a radial test, to assess the efficiency of our method in a 2D situation.

Keywords— Radiation hydrodynamics, artificial intelligence, radiation closure relation, Eddington factor

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