A new high-performance computation method of the Eddington tensor in radiation hydrodynamics simulation

G. Radureau[a], A.I. Comport[b], C. Michaut[a]

a Laboratoire Lagrange ,Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, France
b Laboratory of Computer Science, Signals and Systems (i3S), Sophia Antipolis, France

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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. Various simplified models exist, but in most cases, they are either limited or wrong. It is in this context that the code HADES (Hydrodynamics Adapted to the Description of Supersonic Flows) was developed (Nguyen 2011, Michaut et al. 2011, Michaut et al. 2017). This code solves the general equations of radiative hydrodynamics in the 2D case and uses the M1 model for radiation transfer (Turpault 2003, Dubroca and Feugeas 1999). These simulations require to compute what is called the Eddington tensor which relates the radiative pressure to the radiative energy. This tensor doesn't have an analytical expression in the case of the M1 multigroup model, which consists in considering radiative quantities integrated over bands of frequencies. This issue has been dealt by using heavy search algorithms (Nguyen 2011, Turpault 2003) or using simplified expressions, that aren't general (Vaytet et al. 2011). We have tested multiple approaches using search algorithms, such as the 2D Newton method and the line search algorithm and compared the computation time initialising them with standard values or with neural networks predictions. We also have developed a novel approach consisting in using purely predictions from neural networks to compute the values of the Eddington tensor. Our results show that our new approach using machine learning is the fastest method, while providing solutions with 10-3 % relative errors. We also will show that if more precision is needed, a line search algorithm initialised by machine learning predictions can provide solutions attaining 10-8 % relative error, but it takes more computation time.