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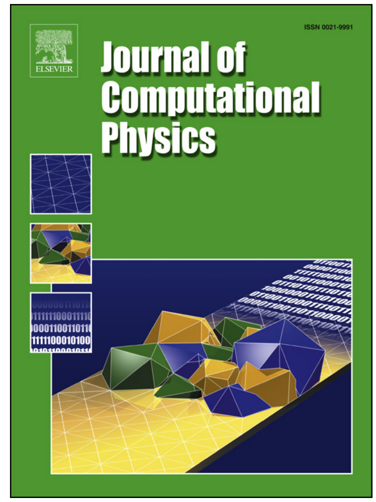

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One-dimensional Lagrangian implicit hydrodynamic algorithm for Inertial Confinement Fusion applications

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Abstract

A new one-dimensional hydrodynamic algorithm, specifically developed for Inertial Confinement Fusion (ICF) applications, is presented. The scheme uses a fully conservative Lagrangian formulation in planar, cylindrical, and spherically symmetric geometries, and supports arbitrary equations of state with separate ion and electron components. Fluid equations are discretized on a staggered grid and stabilized by means of an artificial viscosity formulation. The space discretized equations are advanced in time using an implicit algorithm. The method includes several numerical parameters that can be adjusted locally. In regions with low Courant-Friedrichs-Lewy (CFL) number, where stability is not an issue, they can be adjusted to optimize the accuracy. In typical problems, the truncation error can be reduced by a factor between 2 to 10 in comparison with conventional explicit algorithms. On the other hand, in regions with high CFL numbers, the parameters can be set to guarantee unconditional stability. The method can be integrated into complex ICF codes. This is demonstrated through several examples covering a wide range of situations: from thermonuclear ignition physics, where alpha particles are managed as an additional species, to low intensity laser-matter interaction, where liquid-vapor phase transitions occur.

Keywords: inertial confinement fusion, computational fluid dynamics, Lagrangian scheme

1. Introduction

Inertial Confinement Fusion (ICF) [1, 2, 3] research relies strongly on numerical simulations of the microscopic and fast processes of laser interaction with matter, convergent fuel implosion, and thermonuclear ignition and burning. Numerical codes are required to analyze experimental results and to predict the behavior of configurations not yet attainable in the laboratory. Worldwide, sophisticated computer codes have been developed specifically for this purpose: LASNEX[4] and HYDRA[5] (USA), FCI2[6] (France), LARED[7] (China), and ILESTA[8] (Japan) among others. Such codes include comprehensive modelization of the atomic and plasma processes involved in ICF. Between these processes, hydrodynamics plays always a crucial role. A distinctive feature of ICF problems is the wide range of physical scales to be taken into account. For example, in a typical laser driven target, density in the plasma corona, where laser light is absorbed, is below 10^{-4} g cm^{-3}, while that up to 10^3 g cm^{-3} are reached in the high compressed fuel. Simulations should treat both scales accurately because the compressed configuration, where burning takes place, is determined by the ablation pressure produced by the plasma corona. Other magnitudes are also very uneven: spatial scales range from microns (imploding shell, burning fuel) to centimeters (corona). On the other hand, differently from pure gasdynamics, matter equations of state separate considerably from those of ideal gases. High temperature plasmas should be described with separate temperatures for electrons and ions, whereas that in warm dense matter, phase transitions can occur. These peculiarities make difficult

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