A NUMERICAL SCHEME FOR COLLISIONS OF STARS

Godunov-type Particle Hydrodynamics

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1. INTRODUCTION

Since Lucy [7] and Gingold & Monaghan [3] invented smoothed particle hydrodynamics (SPH), it has been used to study a variety of astrophysical problems. A broad discussion of the method can be found in a review by Monaghan [8]. However, the most serious disadvantage of SPH remains to be overcome: it cannot handle strong shocks accurately. Especially in three dimensional calculation, particles often penetrate each other, and there are typically large post-shock oscillations.

In this paper, a new method to handle shocks in particle hydrodynamics is presented [4, 5]. In this method a smoothing kernel is used to interpolate various quantities in space. This aspect is similar to SPH [8]. However, the integration of the equations of motion is completely different. Here we make use of a Riemann solver which is the main ingredient of Godunov's method [2]. The method may thus be regarded as a multi-dimensional Lagrangian sequel to Godunov's method. Hereafter we call it Godunov-type particle hydrodynamics (GPH).

2. METHOD & EXAMPLES

A brief explanation of the method can be found in Inutsuka 1994 [4, 5]. Similar procedures as MUSCL (van Leer 1979) or PPM (Colella & Woodward 1984) are used to make the accuracy of the method higher order in space. In this case, we require monotonicity algorithms similar to the type of van Leer's[9].

GPH is tested on a variety of 1D, 2D and 3D problems. Here we describe only one of them. It is called "Fifteen Degree Wedge Channel Flow" problem. This is considered by Levy, Powell and van Leer [6], and this is a useful

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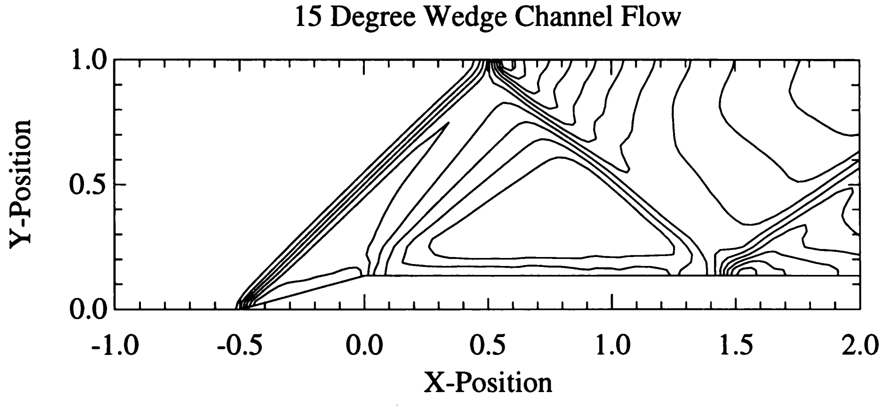

Figure 1. Results of GPH on "15 degree wedge channel flow" problem. Initially 32×96 particles are flowing inside the channel. Mach-number contours from 1.0 to 2.0 are plotted. A variable smoothing length is used.

test to calibrate our method. The geometry is a two-dimensional channel with a 15 degree wedge on the lower wall. A 15 degree expansion corner is also included. The inflow Mach number is two. As apparently noticed, however, this kind of problem is very badly suited for particle method, because (1)we have to realize fixed boundary condition at the wall of the tunnel, and (2)we have to flow particles through the left side boundary continuously. Contrary to the common belief that particle methods such as SPH are not good at this kind of problem, results are excellent.

The present version of GPH has many advantages over standard SPH, especially with strong shocks. In some *astrophysical* problems such as collisions of stars where void fraction is large and free boundary condition is useful, GPH may be still better suited than the "state of the art" finite difference method. Therefore GPH will be a strong tool for *astrophysical* fluid dynamics.

References

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