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Weighted Particle Hydrodynamics without Riemann Solver

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In the field of astrophysics and planetary science, Computational Fluid Dynamics is an essential tool. Problems in these fields often contain inhomogeneities and various effects other than hydrodynamical pressure force, such as self-gravity. Since the Lagrangian method is suitable for dealing with these situations, to date, the Smoothed Particle Hydrodynamics (SPH) has been widely applied.

Recently, however, several critical issues of the standard SPH (SSPH) formulation have been reported. It is pointed out that SSPH has difficulties in dealing with hydrodynamical instabilities. To overcome this problem, several modifications to SSPH have been suggested and tested. As a result, previous works concluded that this issue is resolved. There is, however, another issue that SSPH cannot treat thin gas disk correctly. Since the disk structure is ubiquitous in the field of astrophysics and planetary science, this shortcoming is critical.

Recently, a novel particle-based numerical hydrodynamical simulation method, Weighted Particle Hydrodynamics (WPH), has been proposed. Through several numerical tests, it is demonstrated that WPH overcomes the known shortcomings in SSPH. WPH is an attractive particle-based hydrodynamical scheme.

WPH is, however, based on the Riemann Solver for the evaluation of the inter-particle fluxes. It is not easy to extend Riemann Solver to non-ideal equation of state, though methods exist. In some situations in the field of astrophysics and planetary science, we need to apply non-ideal equation of state. It is difficult to apply WPH to such a situation. In this work, thus, we use the artificial viscosity to WPH, instead of Riemann Solver. With the artificial viscosity we can use WPH for any functional form of the equation of state. In this work, we compare our new approach and the original WPH for hydrodynamical tests. We found that our new approach does not lose any advantage of WPH with Riemann Solver.

Keywords: methods: hydrodynamical, methods: numerical, protoplanetary disks