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Closure of computational fluid models with evolving-background δf kinetics[1]

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A new method of applying simulation particles to close implicit time-dependent nonlinear extended-MHD modeling has been formulated, analyzed, and tested. The new method has three important features that will likely prove useful for any evolving-background δf simulation. First, the fluid equations should be closed with particle information at the momentum-density level to minimize statistical noise from closure terms. Second, the particle motion is described by a particular velocity that represents dynamics without thermal forces, separating the kinetic dynamics from the fluid dynamics. With the use of this particular velocity, there exists symmetry between the δf weight evolution equation and the fluid closure. Third, an optimal prescription for particle shape in velocity space can be derived using Hermite polynomials. The symmetry and optimal shaping together ensure that the numerical kinetic distortion acquires no low-order moments, analogous to the analytical Chapman-Enskog-like approach. They also lead to a conserved energy integral for the discrete nonlinear system, and the r.m.s. particle weight is bounded. With this advance in computation, combined particle-fluid simulation of low-frequency extended-MHD dynamics with majority ion kinetics is now possible. The new method has been implemented for kinetic ion dynamics with fluid electron modeling in the 2D code IMP2. The method successfully reproduces dynamics where the electric field is perpendicular to the magnetic field, including kinetic stabilization of the isothermal g-mode in a slab. Extensions to include temperature gradient and arbitrary polarization are described. Co-author: W. D. Nystrom, *Coronado Consulting*, Lamy, NM

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