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中国科学院数学与系统科学研究院
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三维流体-粒子耦合系统的波现象 (王益)

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In this paper, we investigate the wave phenomena associated with a fluid-particle model described by the multi-dimensional compressible Euler or Navier–Stokes equations coupled with the Vlasov–Fokker–Planck equation (denoted by Euler–VFP or NS–VFP in abbreviation) through the relaxation drag force on the fluid momentum equation and the Vlasov force on the particle transport. First, we prove the globally nonlinear time-asymptotical stability of the planar rarefaction wave to 3D Euler–VFP system, which as we know is the first result about the nonlinear stability of basic hyperbolic waves for the multi-dimensional compressible Euler equations with low order dissipative effects (i.e., relaxation friction damping). This new (hyperbolic) wave phenomena comes essentially from the fluid-particle interactions through the relaxation friction damping, which is different from the interesting diffusive phenomena for either the compressible Euler equations with damping (Hsiao and Liu in *Commun Math Phys* 143:599–605, 1992) or the pure Fokker–Planck equation (Lin et al. in *Q Appl Math* 77(4):727–766, 2019). To prove the nonlinear stability of a planar rarefaction wave, we introduce a new micro-macro decomposition around the local Maxwellian to the Vlasov–Fokker–Planck equation (kinetic part of the 3D Euler–VFP system), which presents an unified framework to investigate the time-asymptotic stability of basic wave patterns to multi-D Euler–VFP or NS–VFP system. In particular, a new viscous compressible fluid-dynamical model is first derived from the Chapman–Enskog expansion for the Vlasov–Fokker–Planck equation, equipped with the isothermal pressure and the density-dependent viscosity coefficient, which takes the same form of the well-known viscous Saint-Venant model for shallow water. Moreover, the nonlinear stability of planar rarefaction wave is also shown for 3D NS–VFP system in terms of the unified framework, and it is further proved that as the shear and bulk viscosities tend to zero, the global solution to 3D compressible NS–VFP system around the planar rarefaction wave converges to that of 3D Euler–VFP system at the uniform rate with respect to the viscosity coefficients.

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