Hybrid fluid/particle methods for kinetic equations describing neutral particles in nuclear fusion plasma-edge modelling

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In nuclear fusion reactors, neutral particles play an important role in shielding the reactor walls and in particular the divertor targets from the hot plasma in which the fusion reactions take place. The neutral particle behaviour is governed by a kinetic equation that is difficult to solve due to the high dimensionality of the phase space and the high collisionality between the neutral particles and the plasma. High dimensionality is typically resolved by resorting to Monte Carlo methods, but in high collisional regimes a pure Monte Carlo solver becomes very expensive. To alleviate the computational cost, recent research focuses on hybrid fluid/particle methods that exploit the high-collisionality of the system [1].
In this talk we will elaborate on a new hybrid fluid/particle method that splits the particle distribution in two phases: a fluid phase and a particle phase. The particle phase is solved using a Monte Carlo scheme, the fluid phase follows a reduced fluid model that is derived from the kinetic equation in the high collisional limit. The two phases co-exist in the whole domain, but the amount of mass in each phase is determined by the local collisionality. This way the amount of particles treated with Monte Carlo is reduced in high collisional regimes, where the cost of Monte Carlo is high, but the reduced fluid model is accurate [2]. In low collisional regimes where the reduced fluid model is not accurate, but Monte Carlo is cheap, most of the mass is in the particle phase.
We anticipate that the new hybrid fluid/particle method enables fast and accurate plasma edge simulations, paving the way towards applications in uncertainty quantification, data assimilation, and ultimately plasma edge code validation.

References

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