Adaptive Multi-Physics Simulations of Collisionless Plasmas

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Collisionless plasmas, mostly present in astrophysical and space environments, often require a kinetic treatment given by the Vlasov equation. Unfortunately, the six-dimensional Vlasov equation is inherently expensive to compute and usually can only be solved on very small parts of the considered spatial domain. However, in some cases, e.g. magnetic reconnection, it is sufficient to solve the Vlasov equation in a localized domain and solve the remaining domain with appropriate fluid models. We present an adaptive hierarchical treatment of collisionless plasmas ranging from fully kinetic, to a 10-moment fluid model incorporating a simplified treatment of Landau damping, to a 5-moment fluid description. To account for separation of electron and ion physics, hybrid stages of mixed electron and ion models are also allowed. As a proof of concept, the full physics-adaptive hierarchy is applied to the Geospace Environmental Modeling (GEM) challenge of magnetic reconnection.