Sonic-flow gyrokinetic simulations with a unified treatment of all length scales

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Tokamak turbulence exhibits interaction on all length scales, but standard gyrokinetic treatments consider global scale flows and gyroscale flows separately, and assume a separation between these length scales. However, the use of a small-vorticity ordering [1, 2] allows for the presence of large, time-varying flows on large length scales, whilst providing a unified treatment including shorter length scales near and below the gyroradius. We present the numerical implementation of the resulting implicit gyrokinetic equations, and provide an interpretation of their meaning, as well as alternative numerical schemes.

The implicit dependences take the form of partial time derivatives of the $\boldsymbol{E} \times \boldsymbol{B}$ flow. These are analogous to those found in the $v_{\|}$ formulation of gyrokinetics for electromagnetic perturbations. We show that we are able to solve our implicit equations with an iterative scheme, where the first iteration uses equations that are analogous to the small-flow limit. The Poisson solver (using the same numerical scheme [3] as the ORB5 code) is capable of solving 3D global tokamak geometry but is used here for slab and cylindrical cases. We present simulation results that demonstrate the effects of sonic flows.

Additionally, we show the differences between the distribution functions for the small-flow and sonic-flow formalisms.

References

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