Strong-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 a numerical scheme for the solution of gyrokinetic equations using such an ordering.

For simplicity, we use two-dimensional electrostatic potential perturbations in slab and cylindrical magnetic geometries. In an analogous way to that of the $v_{\|}$-formulation of gyrokinetics, the partial time derivative of the $E \times B$ flow is present in our Euler-Lagrange and Poisson equations. These terms must be kept to ensure energetic consistency [3]. However, these terms are small compared to all other terms, allowing for the use of an iterative numerical scheme.

Our numerical implementation uses the δf particle-in-cell method [4], and employs an arbitrary-wavelength Poisson solver [5]. We have performed code verification using basic slab instabilities. We present comparative weak- and strong-flow simulation results for centrifugal and drift instabilities. We simultaneously simulate supersonic fluctuating flows at large length scales and the cascade of shorter wavelength flows down to the gyroradius.

References

[1] A.M. Dimits, Physics of Plasmas **17**, 055901 (2010)

[2] B.F. McMillan and A.Y. Sharma, Physics of Plasmas **23**, 092504 (2016)

[3] B. Scott and J. Smirnov, Physics of Plasma **17**, 112302 (2010)

[4] S. Jolliet, A. Bottino, P. Angelino, R. Hatzky, T.-M. Tran, B.F. McMillan, O. Sauter, K. Appert, Y. Idomura, L. Villard, Computer Physics Communications **177**, 409 (2007)

[5] J. Dominski, B.F. McMillan, S. Brunner, G. Merlo, T.-M. Tran and L. Villard, Physics of Plasmas **24**, 022308 (2017)