Two-fold framework for verification of Gyrokinetic codes

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In fusion plasmas the strong magnetic field allows the fast gyro-motion to be systematically removed from the description of the dynamics, resulting in a considerable model simplification and gain of computational time. Nowadays, the gyrokinetic (GK) codes play a major role in the understanding of the development and the saturation of turbulence and in the prediction of the consequent transport. Naturally, these codes require thorough verification and validation

We present a new and generic theoretical framework and specific numerical applications to test the faithfulness of the implemented models to theory and to verify the domain of applicability of existing GK codes. To complete verification process, the underlying theoretical GK model and the numerical scheme must be considered at the same time, which has rarely been done and therefore makes this approach pioneering. At the analytical level, the main novelty consists in using advanced mathematical tools such as variational formulation of dynamics for systematization of basic GK code's equations to access the limits of their applicability. The verification of numerical scheme is proposed via the benchmark effort.

In this work, specific examples of code verification are presented for two GK codes: the multi-species electromagnetic ORB5 (PIC)[1], and the radially global version of GENE (Eulerian)[2]. The proposed methodology can be applied to any existing GK code. We establish a hierarchy of reduced GK Vlasov-Maxwell equations implemented in ORB5 and GENE code using the Lagrangian variational formulation [3]. Then, we derive and include the models implemented in ORB5 [4], [5] and GENE [6] inside this hierarchy. At the computational level, detailed verification of global electromagnetic test cases based on the CYCLONE [7] are considered, including a parametric β-scan covering the transition between the ITG to KBM and the spectral properties at the nominal β value. The extended analysis of those simulation is provided in [8].

References

1. S.Jolliet, A.Bottino, P.Angelino et al. Comp.Phys.Comm., 177 (2007).
2. T.Görler, X.Lapillonne, S.Brunner et al., J. Comp.Phys. 230, 7053 (2011).
3. H. Sugama, Phys. Plasmas, 7(2): 466-480 (2000).
4. N.Tronko, A.Bottino and E.Sonnendrücker, Phys. Plasmas, 23:082505 (2016).
5. N.Tronko, A.Bottino and E.Sonnendrücker, submitted in PPCF, invited paper.
6. N.Tronko, T.Görler, D.Told, A.Bottino and E.Sonnendrücker, to appear in special issue of APS DPP meeting in Phys.of Plasmas, invited paper.
7. A.Dimits, G.W. Hammett, C.Kim et al. Phys. Plasmas, 7(3): 969-983 (2000).
8. T.Göerler, N. Tronko, W. Hornsby et al. Phys. Plasmas, 23:072503 (2016).