Gyrokinetic global full-f flux-driven simulations

V. Grandgirard, J. Abiteboul, G. Dif-Pradalier, X. Garbet, Ph. Ghendrih
G. Latu, Ch. Passeron, Y. Sarazin, A. Strugarek, D. Zarzoso
Association Euratom-CEA, CEA/DSM/IRFM Cadarache, France

J.P Braeunig, N. Crouseilles, E. Sonnendrücker
IRMA, CNRS-Université Louis Pasteur, 67084 Strasbourg, France.

Predicting the performance of fusion plasmas in terms of amplification factor, namely the ratio of the fusion power over the injected power, is among the key challenges in fusion plasma physics. In this perspective, turbulence and heat transport need being modeled within the most accurate theoretical framework, using first-principle non-linear simulation tools. The gyrokinetic equation for each species, coupled to Maxwell's equations are an appropriate self-consistent description of this problem. A new class of global full-f codes has recently emerged, solving the gyrokinetic equation for the entire distribution function on a large radial domain of the tokamak and using some prescribed external heat source [1]. This approach thus avoids any scale separation that would introduce unnecessary limitation in the validity of the simulations. In particular, large deviations in both space propagation and velocity structure are readily expected during non-local transport events the so-called avalanches. Such simulations are extremely challenging and require state-of-the-art high performance computing (HPC).

The non-linear global full-f gyrokinetic 5D code GYSELA , which focuses on the electrostatic toroidal branch of the Ion Temperature Gradient driven turbulence with adiabatic electrons, is one of them [2]. As an example, a simulation very close to ITER-size scenario ($\rho_* = 1/512$) performed on a quarter of torus with additional heating power of 60 MW during 1 ms has required 3.10^{11} grid points in 5D phase-space and 6.210^{6} core-hours (31 days of CPU time on 8 192 cores). The particularity of the GYSELA code is to solve the self-consistent problem on a fixed grid with a Backward Semi-Lagrangian scheme [3]. The advantages and drawback of such a scheme will be discussed and more precisely : (i) the different numerical locks which have been recently removed to obtain a relative efficiency of 78% on 64k cores ; (ii) and the high level of accuracy which has been obtained for the force balance equation and the toroidal momentum conservation equations [4]. Such accuracy allows one to analyse in detail the transport and source/sink of momentum in the absence of injected torque providing a complete description of mean flows and radial electric field.

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[4] Abiteboul J et al., *Conservation equations and calculation of mean flows in gyrokinetics*, accepted in PoP 2011.