Modelling Coupled Ion and Electron Scale Turbulence in Magnetic Confinement Fusion Plasmas

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The turbulent transport of particles, momentum, and energy limits confinement in magnetic confinement fusion devices. Theoretical, numerical, and experimental evidence suggests that turbulent ion transport is primarily caused by turbulence with characteristic spatial scales comparable to or larger than the ion Larmor radius. In addition to these ion Larmor scale transport mechanisms, it is known that there can also be significant transport of heat by electrons due to turbulence driven at the electron Larmor scale.

Due to the largeness of the ion to electron mass ratio direct gyrokinetic simulations of turbulence including both the ion and electron Larmor scales have only recently become possible, with most work to date treating the ion and electron scales separately or using a reduced mass ratio [1]. Simulations involving both ion and electron scales indicate that the cross-scale coupling can be important for matching anomalous transport levels with experiment [2]. However, the extreme expense of a realistic mass ratio direct simulation limits the usefulness of multiscale direct simulations for fully understanding the physics of the cross-scale interaction and its consequences. A reduced, less expensive, gyrokinetic model would help shed light on the physics of the interaction and when we can expect it to be important.

We present such a reduced set of coupled gyrokinetic equations for the ion and electron scales. These equations are derived asymptotically from the full gyrokinetic equation using a multiscale method, with the expansion parameter being the square root of the electron to ion mass ratio. This expansion exploits the separation between ion and electron Larmor scales in the plane perpendicular to the magnetic field line, and the separation between the ion and electron thermal speeds. We discuss the new cross scale coupling terms appearing in these equations, and present results from preliminary simulations using these new terms which have been implemented in the local gyrokinetic code GS2.

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 633053 and from the RCUK Energy Programme [grant number EP/P012450/1]. The views and opinions expressed herein do not necessarily reflect those of the European Commission. The authors acknowledge EUROfusion, the EUROfusion High Performance Computer (Marconi-Fusion), and the use of ARCHER through the Plasma HEC Consortium EPSRC grant number EP/L000237/1 under the projects e281-gs2.

References

[1] N. T. Howard, C. Holland, A. E. White, M. Greenwald, and J. Candy. Synergistic cross-scale coupling of turbulence in a tokamak plasma. Physics of Plasmas, 21(11):112510, 2014. doi: http://dx.doi.org/10.1063/1.4902366.URL http://scitation.aip.org/content/aip/journal/pop/21/11/10.1063/1.4902366

[2] N. T. Howard, C. Holland, A.E. White, M. Greenwald, and J. Candy. Multi-scale gyrokinetic simulation of tokamak plas- mas: enhanced heat loss due to cross-scale coupling of plasma turbulence. Nuclear Fusion, 56(1):014004, 2016. URL http://stacks.iop.org/0029-5515/56/i=1/a=014004