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Kinetic simulations of electron transport in plasmas relevant for fusion and space applications

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Electron transport driven by instabilities is a universal feature in high- and low-temperature magnetized plasmas. Only fairly recently has it become feasible to simulate large-scale plasma transport within the framework of kinetic theory of gases and only the latest additions to computing power have enabled this to be done up to electron scales in tokamak plasmas and system size in Hall-effect thruster plasmas. Emerging evidence shows that complicated interplay over vastly different scales of physics affects transport, making both multi-scale gyrokinetic continuum simulations of tokamak transport and particle-in-cell simulations of Hall-effect thrusters a very interesting prospect indeed.
A lot of indirect evidence suggests that electron temperature gradient (ETG) turbulence is a key player in magnetized fusion plasmas. ETG turbulence is considered to contribute to the overall electron heat flux and to affect ion-scale turbulence by reducing the effectiveness of shear-flow stabilization. Interestingly, ETG turbulence in our simulations exhibits a symmetry breaking as a result of the presence of a low-Z impurity species at significant density. We will elaborate on this point via continuum gyrokinetic simulations.
Anomalous conductivity due to instabilities is an important feature of $E \times B$ driven plasmas (see Refs 1,2). Kinetic simulations show that cascades to large scales occur in density fluctuations as well as the anomalous current. Long term behavior of the system has proven to be surprisingly challenging to simulate numerically with sufficient accuracy. We discuss recent simulations of fluctuations in Hall-effect thrusters and associated heating observed in simulations, as well as analytical theory behind these phenomena.

[1] S. Janhunen et al., Physics of Plasmas 25 (1), 011608 (2018)
[2] S. Janhunen et al., Physics of Plasmas 25 (8), 082308 (2018)

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