Simulation of gyrokinetic turbulence in stellarators

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Magnetic-confinement fusion devices come in two shapes: the “plain-donut” tokamak and the “curly-donut” stellarator. Owing to its technological simplicity, the tokamak line has been enjoying popularity for the past several decades. However, the recent commissioning of the one-billion Euro stellarator Wendelstein 7-X experiment in Greifswald as well as great strides in the computational efficiency of simulation codes at the peta-scale level, have rendered the stellarator an important contender for the next fusion reactor. Both in tokamaks and stellarators, turbulence seems to be playing a key role, limiting the confinement and thus the performance of the experiment. Ion-scale turbulence in stellarators is typically localized poloidally, contrary to tokamaks where the structures are distributed evenly over the entire outboard side. This localization is found to be responsible for a number of features. For instance, 3D shaping tends to create locations where adjacent magnetic surfaces are dense, and therefore the local pressure gradients are strong, exacerbating turbulent heat fluxes. This unfavorable effect is found, however, to be alleviated significantly thanks to localization, since the transport calculated through the entire magnetic surface is much smaller than the increased local one [P. Xanthopoulos et al., Phys. Rev. X. 6, 021033 (2016)]. Another remarkable feature of stellarator transport is the suppression of turbulence driven by the electron temperature gradient. This phenomenon resembles early tokamak simulations where the global magnetic shear is artificially set to negative values. Stellarators, on the other hand, are naturally characterized by strong negative local shear which imposes a similar effect on small scale turbulence. In addition, the strong local shear is found to impede the decay of zonal flows in stellarators. Despite the positive inherent features of stellarator turbulence, there seems to exist enough room for further optimization of the magnetic field towards lower levels of turbulent transport. Genetic algorithms have been implemented which are able to perform global search in the vast space of stellarator configurations, in view of the large number of free parameters, and novel stellarator designs have emerged from this effort, improving on the existing ones [P. Xanthopoulos et al., Phys. Rev. Lett. 113, 155001 (2014)].