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Gyrokinetic simulation of micro-turbulence in stellarators

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Most 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 Wendelstein 7-X stellarator experiment in Greifswald (Germany) has rendered the stellarator an important contender for the next fusion reactor. Thanks to great strides in the computational efficiency of simulation codes at the peta-scale level [1], we now understand that turbulence could play a key role, limiting the confinement and thus the performance of an optimized (with respect to neoclassical transport) stellarator. As shown in Figure 1, 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 favorable 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 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 [2]. In addition, localization in stellarators is found to impede the decay of zonal flows in stellarators [3], which act as a stabilizing mechanism for turbulence. Despite these 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, and novel stellarator designs have emerged from this effort, improving on the existing ones [4].

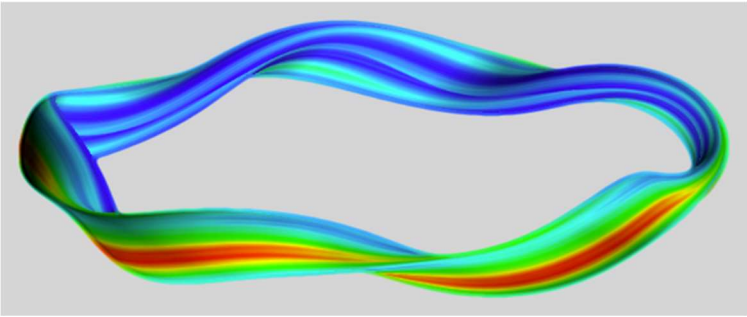

Figure 1: *GENE simulation of the density fluctutations caused by ion temperature gradient turbulence on a magnetic flux surface of the Wendelstein 7-X stellarator.*

References

[1] www.genecode.org
[2] P. Xanthopoulos et al., Phys. Rev. X 6, 021033 (2016)
[3] G. Plunk, P. Xanthopoulos and P. Helander, Phys. Rev. Lett. 118, 105002 (2017)
[4] P. Xanthopoulos et al., Phys. Rev. Lett. 113, 155001 (2014)