Geometric considerations for zonal flow activity in stellarators as the starting point for transport modeling

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Turbulent transport in fusion plasmas causes limited performance present-day experiments. This has become the dominant transport channel, after optimization routines have successfully addressed neoclassical transport. The further optimization of stellarators will focus on suppressing turbulent fluctuations [1, 2] by exploiting the three-dimensional freedom of the magnetic field. This task requires robust transport models to enable fast predictions, preferably based on the cumbersome geometry of stellarators.

While the current state-of-the-art models are mainly based on extrapolations from linear physics, the nonlinear character of turbulence calls for the inclusion of the mechanisms responsible of turbulence saturation. We focus on developing a transport model that includes zonal flows as saturation mechanisms of ion-temperature-gradient (ITG) turbulence in tokamak.

In this work, we will present the characteristics of zonal flow levels in various geometries within the configuration space of Wendelstein 7-X using the gyrokinetic code GENE [3, 4]. It is found that the exponential decay of the linear zonal flow response is highly affected by the characteristic geodesic curvature lengthscale, opposite to what is seen in nonlinear simulations. At high temperature gradients, zonal flows begin to play a decreasing role in regulating transport levels. However, the shape of the turbulent mode is increasingly modulated by the drift well, where we define also a characteristic lengthscale.

Finally, we propose that these lengthscales can be extracted from the magnetic field geometry and directly related to zonal flow generation and decay. Our results are analogous to the geometric conjectures for tokamaks that have been previously explored and presented by Barnes [5]. Finally, the parameters we present will serve to set the basis for improved stellarator transport prediction.

References

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