Zonal flows as mediators of energetic particles and turbulence

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Zonal flows [1] are axisymmetric perturbations of tokamak plasmas that have been shown to play an important role in the self-consistent saturation of turbulence and the reduction of heat and particle transport. Understanding its physics and predicting its expected saturation level is primordial in designing future cost-effective thermonuclear tokamak reactors. In this work, we discuss the physics of the major excitation mechanisms of zonal flows, laying emphasis on the dominant nonlinear effects that are important in their dynamics and the role played by energetic particles. The role of each of these mechanisms is studied numerically with global electromagnetic particles in cell gyrokinetic codes ORB5 using the JET tokamak reactor as a test case [2], Fig 1.

Figure 1: ORB5 simulation showing a poloidal cross-section snapshot of the scalar potential of the JET reactor. (a) Electrostatic turbulence simulation(b) ZF pattern driven by energetic particles excited Alfven modes.

References

[1] Hasegawa, et al., *Phy. Fluids*, **22**, 2122–2129 (1979).

[2] J. N. Sama, et al., *arXiv*, 2401.04501 (2024).