Zonal flow generation by nonlinear polarization and high relative fluctuation amplitudes

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Zonal flows are of central importance for transport regulation in fusion plasmas [1,2]. The importance of the Reynolds stress for zonal flow generation is indisputable [1-3], but also other stresses like the Maxwell or diamagnetic stress can be significant in magnetized plasmas. Recent theoretical and experimental studies of poloidal mean flow in edge turbulence indicate that unresolved mechanisms beyond the Reynolds stress exist and that steep density gradients and large fluctuations affect the poloidal mean flow dynamics.

In this contribution we generalize the theory of poloidal ExB mean flows to nonlinear polarization and high fluctuation amplitudes. To this end, we decompose the density and electric potential of a full-F gyro-fluid model [4] with the help of a density weighted Favre average, a well-known decomposition strategy in compressible fluid dynamics, to derive the evolution equation for the density weighted poloidal mean flows. This allows us to identify novel agents in the mean flow dynamics, which become significant either for high relative density fluctuations or steep density gradients. We confirm the derived mechanism for radial advection of zonal flows (cf. Figure 1) with the help of fully nonlinear numerical simulations of drift wave-zonal flow dynamics, which are accomplished by the presented extension of the Hasegawa-Wakatani model to the full-F framework. Additionally, we show how the density weighted mean flow dynamics are distributed among the proposed actors when we vary the collisionality or initial gradient length.

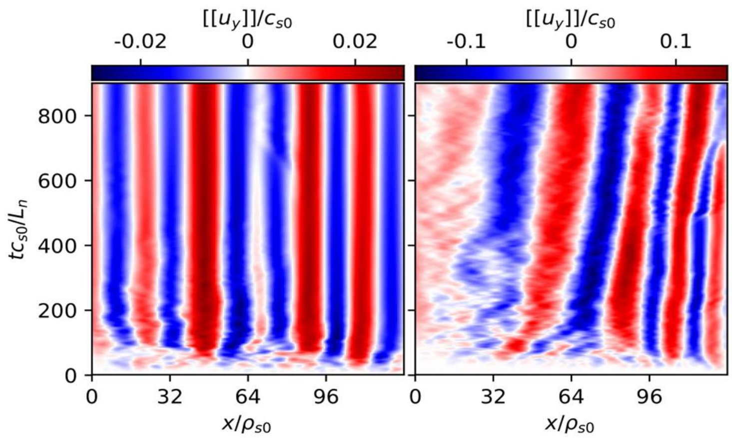

Figure 1: *The spatio-temporal zonal flow evolution of the density weighted mean poloidal velocity is shown for two different density gradient lengths. The radially outward advection of zonal flows for the four times smaller gradient length (right) is clearly visible.*

References

[1] P. H. Diamond, S.–I. Itoh, K. Itoh, T. S. Hahm, Plasma Physics and Controlled Fusion 47, R35 (2005)
[2] Ö. D. Gürcan, P. H. Diamond Journal of Physics A: Mathematical and Theoretical 48, 293001 (2015)
[3] P. H. Diamond, Y.–B. Kim, Physics of Fluids B: Plasma Physics 3, 1626-1633 (1991)
[4] J. Madsen, Physics of Plasmas 20, 072301 (2013)