Non-Oberbeck-Boussinesq zonal flow generation

M. Held[1], M. Wiesenberger[2], R. Kube[3], A. Kendl[1]

[1] *Institute for Ion Physics and Applied Physics, Universität Innsbruck, A-6020 Innsbruck, Austria,*

[2] *Department of Physics, Technical University of Denmark, DK-2800 Kgs. Lyngby, Denmark*

[3] *Department of Physics and Technology, UiT The Arctic University of Norway, N-9037 Tromsø, Norway*

In magnetized fusion plasmas zonal flows (ZFs) are key players for the reduction of the radial transport of particles and heat and for the transition to improved confinement regimes in tokamaks [1, 2]. Virtually all of the work on ZF theory so far rely on δf models [1], which invoke the so called Oberbeck-Boussinesq (or thin layer) approximation. However, the latter breaks down, if the background density varies over more than one order of magnitude or if the relative density fluctuations exceed roughly 10 percent. These circumstances prevail in the edge of tokamak fusion plasmas.

Non-Oberbeck-Boussinesq (NOB) effects on ZF generation are an unresolved issue. However, recent investigations of poloidal ZFs in the edge of fusion plasmas indicate that unknown mechanisms beyond the Reynolds stress exist and that NOB effects affect the poloidal ZF dynamics [5, 6].

In this contribution we present novel mechanisms for zonal flow (ZF) generation for both large relative density fluctuations and background density gradients. In this non-Oberbeck-Boussinesq regime ZFs are driven by the Favre stress, the large fluctuation extension of the Reynolds stress, and by background density gradient and radial particle flux dominated terms. Simulations of a nonlinear full-F gyro-fluid model [3] confirm the predicted mechanism for radial ZF propagation (cf. Fig. 1) and show the significance of the NOB ZF terms for either large relative density fluctuation levels or steep background density gradients.

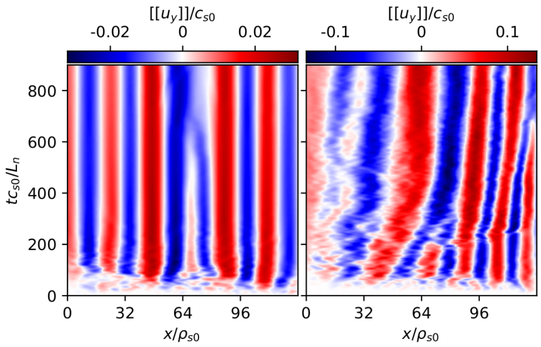

Figure 1: The spatio-temporal zonal flow evolution of the density weighted mean poloidal velocity is shown for two different density gradient lengths. The radially outward advection of zonal flows for the four times smaller gradient length (right) is clearly visible.

References

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