New perspectives on large scale flows and their interplay with turbulence

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It is now well admitted that large scale flows – such as self-generated Zonal Flows or equilibrium flows – efficiently contribute to ion scale turbulence regulation. The mechanism by which Zonal Flows emerge and self-organize in long lived quasi regular staircase structures remains however poorly understood. Also, the possible impact on core turbulence and transport of the poloidally asymmetric flows in the Scrape-Off Layer (SOL) is still a matter of active research, especially regarding the access to improved confinement regimes characterized by an edge transport barrier.
This paper addresses both issues and presents critical advances by means of flux driven gyrokinetic simulations with the GYSELA code and of a comprehensive 1D nonlinear reduced model for interchange turbulence.

The 1D model reveals that Zonal Flows can emerge due to a phase instability, leading to the exponential growth of the tilt of the vortices. This mechanism appears to be dominant when the Zonal Flows radial structure is commensurable to the box size, and competes with an instability of the amplitude of the fluctuations themselves in the case of smaller size staircases. The search for such behaviors in 5D GK simulations will be reported. Also, low dimensional simulations allow one to explore the long term behavior of staircases. Merging is sometimes observed. Yet, its complex dynamics does not offer so far a clear understanding of the underlying mechanism.
In limiter configurations, modelled via immersed boundary conditions in GYSELA, ion orbit losses already give rise to a non-vanishing radial electric field which adds up to the expected inversion of Er across the separatrix. The physics will be reviewed in axi-symmetrical and non axi-symmetrical (ripple) magnetic configurations. In addition, we commonly observe the onset of steep variations of Er and notably the development of a well at the transition region between closed and open field lines. In its vicinity, instabilities develop which, depending on underlying plasma parameters may be of interchange nature or bear analogies with the transverse Kelvin-Helmholtz instability. We will detail the mechanism by which, mediated by large scale asymmetric poloidal flows, it appears to propagate both inwards and outwards, hence bridging SOL and core turbulence. Last, first evidence of core turbulence modification by edge flows will be discussed.