Rotation and Staircases in Tokamaks: on the Hierarchy of Flows near Criticality

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What will an attracting fixed point for the dynamics look like? What will the flow patterns look like in steady-state? Mounting evidence suggests that the ability to describe self-organisation at meso-scales and larger is key to answering the latter questions. Beyond their academic interest, the questions above have important practical consequences on our understanding of flow organisation [1], of the hierarchy of shears [2] and possibly of the nature of transport itself.

Allowing for the mean profiles to self-organise given the combined action of small-scale turbulence, large-scale neoclassical effects and an external distribution of sources and sinks [3] certainly represents a challenging new problem for gyrokinetics. The critical state –*i.e.* the attracting fixed point for the dynamics– in flux-driven gyrokinetics displays some interesting novel features: in addition to the now commonly observed heat and momentum avalanches [4], long-lived metastable states are found. These states result from a clustering tendency of the system which leads to the emergence of an organised "staircase" [1] pattern of flows. A strong imprint of this flow structure is found on the mean profiles and on the turbulent stresses.

The imprint on the mean profiles results in an additional equilibrium $\mathbf{E} \times \mathbf{B}$ shear generated through turbulence-induced corrugations of these mean profiles. This mean shear is found to be dominant as compared to the usual low frequency zonal flow shear, questioning our current understanding of the hierarchy of shears. It also leads to a strong nonlocal, nondiffusive character of the heat conduction [1]. Turbulent stresses are also impacted by this clustering behaviour and are shown to explain the possible non-neoclassical behaviour of poloidal momentum [2,5-7]. Further ongoing work is concerned with understanding why this flow pattern emerges, how it reconciles with heat avalanching and how it may connect to ordering parameters within the plasma. In particular the influence of the safety factor is still unclear. To this end, a scan in its profile is presented, either parabolic, reversed and flat.

References:

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