Contribution ID: **213**

Type: **Poster**

Validation of Self-Organisation Dynamics in Fusion Plasmas

Wednesday, 19 October 2016 08:30 (4 hours)

Large-scale global organisation of turbulence has attracted persistent interest in fusion plasmas as a means to control transport and access improved confinement. It has practical consequences on zonal flow formation and sustainment, on front propagation—a natural tendency in heat flux-driven turbulence—or on the spreading of turbulence in regions of quasi-linear stability.
In this paper we present novel results based on a careful confrontation between flux- and gradient-driven gyrokinetics using the GYSELA code and recent experimental data. We present the first experimental evidence of ExB staircase identification using state-of-the-art ultrafast sweeping reflectometry. The ExB staircase reconciles seemingly antagonistic trends in turbulence self-organisation whilst spontaneously generating sets of weak transport barriers that organise transport on global scales. A large experimental database of several hundred-staircase signatures is analysed. In addition to successfully confirming several of its numerically-predicted properties, interesting novel features are reported: (i) an abrupt apparent disappearance of this structure at the LOC/SOC transition is observed, associated with a change in the nature of the turbulence (electron versus ion drift waves) that is still enigmatic at present, as well as (ii) a possible route to gyro-Bohm breaking through staircase permeability, especially at low "rho_star" and in the far-core, near-edge so-called No Man's Land region.
This also led us to elucidating key aspects of the controversial "shortfall problem" there. The combination of flux drive and Scrape-Off-Layer-like boundary are key players of the No Man's Land dynamics, especially as core turbulence spreads into the marginally stable edge, enhanced through a "beach effect". A careful comparison within the same numerical framework between flux- and gradient-driven gyrokinetic computations of the same L-mode plasmas leads to the observation in certain plasma conditions of a shortfall in the gradient-driven case and not in the flux-driven case. Interpretation is given of this result in terms of an inhibition of spreading associated to a weakened staircase—avalanche interplay. An isotope effect on transport and on flow generation is also discussed.

Paper Number

TH/P3-5

Country or International Organization

France

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Session Classification: Poster 3

Track Classification: THC - Magnetic Confinement Theory and Modelling: Confinement