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Transport in Fusion Plasmas: Is the Tail Wagging the Dog?

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Magnetically-confined thermonuclear plasmas hold the promise of sustainable and safe nuclear fusion production on Earth. For over three decades, the observation of rapid core confinement improvement upon favourable modifications of edge operating conditions has been a nagging source of puzzlement for experimentalists investigating conditions for a lasting source of fusion energy in tokamaks [1]. The transport properties of drift-wave turbulence and the interaction of the confined plasma with its material boundaries have long been recognised as essential to the resolution of this conundrum [2]. Key aspects of the turbulent dynamics in the plasma edge are poorly quantified, owing to the disparity of temporal and spatial scales and the inadequacy of performing scale separations. Here we show, relaxing oft-made scale separation assumptions that a narrow region at the interface between open and closed magnetic field lines is central to explaining the transport properties of turbulence, globally. This `nonlocal' influence is mediated through localised interactions with the material boundaries and is responsible for the emergence of a stable and localised modest but persistent transport barrier in the plasma edge [3]. As this region is central to confinement, we anticipate our results to contribute addressing several ongoing problems for fusion research. For instance, in suggesting a framework where turbulence is not only locally driven by the local gradients but actually nonlocally [4] controlled by fluxes of turbulence activity, primarily though not exclusively coming from the edge [5,6]. This impacts our understanding of transport barrier formation and access to high confinement regimes as well as in the longer run our understanding of deposition patterns on plasma facing components, highly relevant to the safe operation of large burning plasma systems such as Iter.

References

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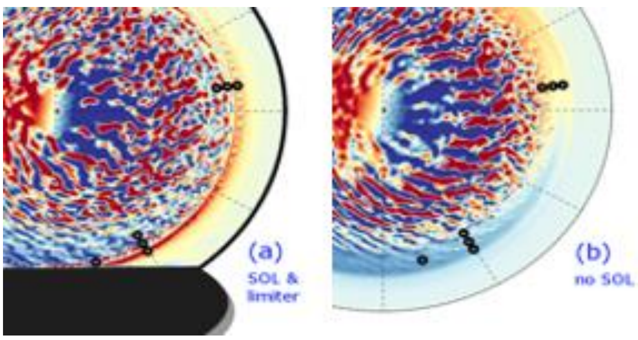

Fig 1. GYSELA calculation of Tore Supra-like parameters, with a penalised limiter (a) versus with a poloidally uniform boundary (b).

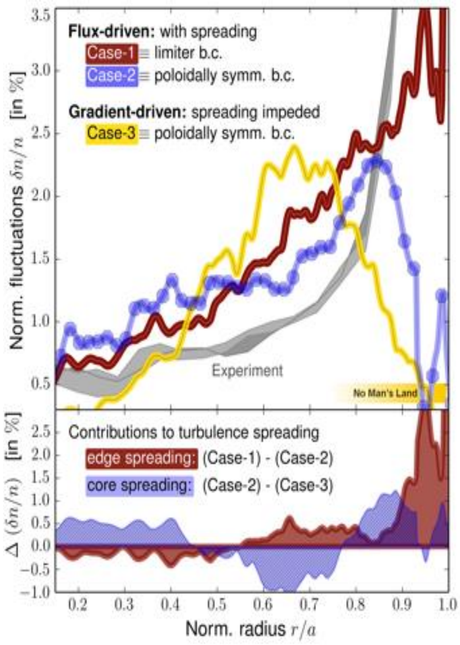

Fig 2. Fluctuation profile and spreading contributions, modifying boundary conditions.