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Growth estimates, control and structures in a two-field model of the scrape-off layer

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Anomalous transport, turbulence and generation of large-scale structures in the scrape-off layer (SOL) of tokamaks are some of the main issues that control machine performance (via impurity contamination) and the life expectancy of plasma-facing materials, and here one tries to achieve some understanding of these questions through the theoretical analysis of a reduced two-dimensional two fluid (density plus vorticity) model of the SOL. The model is built around a conservative system describing transport perpendicular to the magnetic field in a slab geometry, to which terms are added to account for diffusion and parallel losses (both for particles and current) and to mimic plasma flow from the core (in the form of a source). Nonlinear estimates for the growth rates are derived, which show the growth in the density gradient to be controlled by the vorticity gradient, and vice-versa, therefore suggesting a nonlinear instability in the model. The possibility of controlling fluctuations by means of a biasing potential is confirmed (negative polarisations being shown to be more effective in doing so, thus providing an explanation for what is seen in experiments), as well as the advantage in reducing the inhomegeneity of the magnetic field in the SOL to decrease plasma turbulence there. In addition, focusing on the conservative part of the equations, exact solutions in the form of travelling waves are obtained which might be the conservative ancestors of the collective structures (so-called blobs) that are observed in experiments as well as in numerical simulations.

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