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# Magnetic Structure of Turbulence-Driven Magnetic Islands

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Neoclassical tearing modes (NTM) are metastable magnetic islands in tokamaks; however, they appear frequently in experiments without any noticeable triggering event. In order to understand this, it has been numerically shown that turbulence can create a seed island by mode coupling [1,2,3], even remotely [4] ; such a seed island has been shown in 2D models to further grow from the NTM mechanism [5]. This amplification happens because of the island-induced pressure profile flattening. In turn, this flattening comes from the transport properties of the island, which are a consequence of the magnetic field perturbation. Therefore, characterizing magnetic transport both inside and outside a turbulence-driven magnetic island is crucial to understanding NTM triggering.
In this work, 3D reduced-MHD simulations of flux-driven ballooning turbulence are used to study the seed island creation in regimes where the classical tearing mode is linearly stable. A localized pressure source is used to control the radial position and strength of the turbulence. Several large-scale modes of island parity are generated in the nonlinear phase with different helicities, and stochasticity appears progressively in the region between those islands, although with significant stickiness of the field lines close to remaining KAM tori.
In this situation, even the definition of island size (or island boundary) becomes ambiguous. This is of particular importance since it is expected that flattening of the pressure profile appears only above a critical island size, depending on the ratio of parallel to perpendicular transport [6]. Several definitions of island size are compared, and a method for sorting magnetic field lines and calculating island width from Poincaré plots is presented.
We next study the transport properties of those magnetic fluctuations, first in an academic field featuring two large-scale modes. In particular, the role of Lagrangian Coherent Structures (LCS) are investigated from a statistical point of view. It is shown that field lines escape a tube over a finite length which is independent of tube size. However, this length is not uniform in the chaotic sea, and is minimum (indicating maximal transport) in the vicinity of LCS. Combined with the fact that LCS are not fixed but vary with time and velocity of particles, this could reduce their effectiveness as transport barriers when other processes exist.
Next, the robustness of those LCS with respect to small-scale turbulence is assessed. They are shown to persist even when the magnitude of small-scale fluctuations is enough to render the whole domain stochastic. Moreover, varying the wave number range of small scale fluctuations, we extract a critical magnetic spectrum determining whether LCS can be destroyed by small scale fluctuations.
Finally, analyzing MHD simulations in the light of the above results, we assess the role of the various scales in the onset of stochasticity and magnetic transport. In particular, we show that the main contribution to stochasticity comes from non-linearly generated large-scale modes.
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