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Electron temperature barriers as Lagrangian Coherent Structures in RFX-mod and in 3D nonlinear MHD

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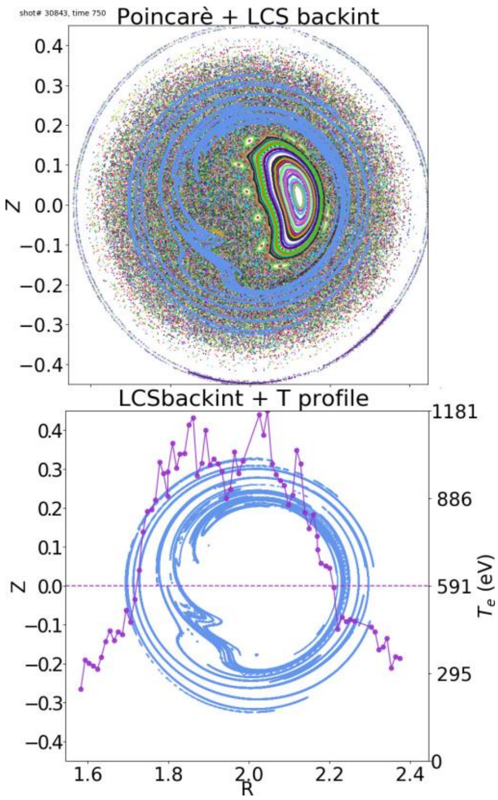
The formation of Electron Transport Barriers (ETBs) with impact on transport and dynamical regimes is common to the main configurations for the magnetic confinement of hot plasmas: tokamak, stellarator, and reversed-field pinch (RFP). One goal of magnetic confinement research is to control and manipulate these barriers by exploring methods to understand, trigger, sustain, and optimize their properties.

In this work we describe and use Lagrangian Coherent Structures (LCSs), first investigated in fluid dynamics, as basic entities sustaining ETBs. In fact, LCSs are material lines advected by the fluid which organize the flow transport processes [1, 2]. They are computed numerically looking for the most repulsive material lines present in the flow map of the magnetic field. Thus, they divide the phase space in regions that tend not to communicate one with the other [3], creating a barrier.

In this talk we show LCSs at play in both 3D nonlinear MHD modelling and experimental situations. First, we show results obtained from the RFX-mod experiment in reversed-field pinch (RFP) configuration: there, when the current increases over a threshold around 1MA, the plasma spontaneously organizes itself on a quasi-helical shape generating a region of high electron temperature. We proceed as follows: on the one hand we get Thomson Scattering measurements of the electron temperature at significant temporal snapshots, on the other we reconstruct the magnetic field at the selected times and compute its LCSs (thus it is assumed that electrons follow magnetic field lines). The Figure shows a comparison between LCSs and the electron temperature profile during a good quasi-helical state (RFX-mod shot #30843, time 75ms): it shows that LCSs behave as barriers to the motion of magnetic field lines, and they coincide with the location of highest electron temperature gradients.

Second, we show the insight provided by the LCSs approach taking advantage of the MHD magnetic field computed by 3D nonlinear simulations of both RFP [4, 5] and tokamak configurations, made with the SpeCyl [6] and PIXIE3D [7] codes. We will show preliminary results of the technique in different plasma scenarios, particularly in the case of tokamak sawtoothing, an example that opens the way to several applications like RMP-penetrated plasmas, mitigated ELM and disruption scenarios.



Lagrangian Coherent Structures are the blue curves. When a stochastic magnetic field is observed through a Poincaré plot only, LCSs can't be detected, see upper panel. Their presence is linked to the measurement of extremely high electron temperature gradients.

References:
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