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Lagrangian Coherent Structures to study and understand chaotic transport

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The understanding of transport phenomena is one of the most challenging tasks in fusion plasmas. Among transport mechanisms, chaotic transport of magnetic field lines acquires a crucial importance due to the strong anisotropy that governs the plasma transport. Despite their apparent “randomness”, chaotic magnetic fields lines display a remarkable amount of structures. These structures have a fundamental impact on the plasma transport.

For the study of magnetic field dynamics, we exploit the so-called Lagrangian Coherent Structures (LCSs)[1]. Such LCSs, borrowed from fluid dynamics theory, can be considered as the hidden skeleton governing the dynamical system. An LCS is a generalization for a finite time interval and for a generic dynamical system of what manifolds are for Hamiltonian systems. In this talk, we show that such structures can be particularly useful for underlying the hidden patterns governing the motion of magnetic field lines in chaotic magnetic fields. After the description of the algorithm we use to detect the structures[2], we focus on its first applications to Reversed Field Pinch (RFP) numerical simulations[3], although many other applications to plasma physics modelling are planned. We show how LCSs help to understand the dynamics of field lines and how LCSs suggest the presence of cantori[3], that can be naively considered as flux surfaces with gaps. Once chaos is spread, cantori are particularly useful since they act as partial transport barriers.

In the second part of the talk we focus on heat transport equation and the comparison between temperature profiles and topology of the LCSs[2]. We provide evidence that numerical simulations are able to reproduce the temperature profiles similar to those observed in reversed field pinch experiments and that LCSs successfully predict the location of temperature gradients (see fig 1) for both partially and totally chaotic fields. The results suggest that, inside the chaotic region, the field-lines motion is far from stochastic and that the presence of hidden patterns allows the development of high temperature gradients.

Although most of our analysis have been done upon magnetic fields coming from numerical simulations, in the last part of the talk we show few preliminary results concerning the application of this technique to experimental magnetic fields of the RFX-mod device [5], Padua.

References

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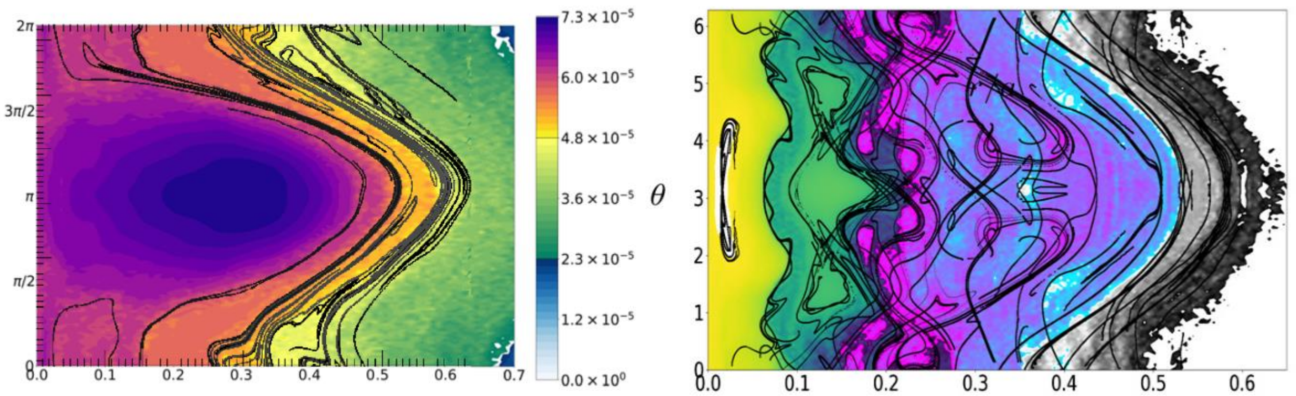

Figure 1: LCS (black curves) and Temperature contour for a *partially* chaotic magnetic field (left) and for a totally chaotic magnetic field (right)