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Temperature gradients are supported by cantori in chaotic fields

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TOPIC :

With the tantalizing prospect that localized regions of chaotic magnetic field can be used to suppress ideal instabilities in fusion devices, as suggested by the resonant magnetic perturbation (RMP) experiments on DIIID, it becomes necessary to understand the impact of chaotic fields on plasma confinement, particularly so considering that RMP fields are being considered as an ELM mitigation strategy for ITER. Using a model of heat transport with separate parallel and perpendicular thermal diffusion coefficients, $\kappa_\parallel$ and $\kappa_\perp$, this paper will show that chaotic fields can support significant temperature gradients, despite the fact that flux surfaces may be destroyed by perturbing fields. The remnants of the irrational flux surfaces, the cantori, present extremely effective *partial*-barriers to field-line transport, and thus present effective barriers to any transport process that is dominantly parallel to the field.

For fusion plasmas the ratio $\kappa_\parallel/\kappa_\perp$ may exceed 10^{10}. The temperature adapts to the fractal structure of the magnetic field. To show the connection between the fractal structure of the magnetic field and the *near*-fractal structure of the temperature T, we develop *chaotic*-magnetic coordinates [PRL **100**, 095001 (2008)]: coordinates adapted to the invariant structures of the field line flow. The temperature may be written in chaotic coordinates as $T = T_o(s) + \delta T(s,\theta,\phi)$, where s is a radial coordinate. $T_o(s)$ is generally a smoothed devil's staircase: flat across the rationals (islands), with gradients on irrationals (cantori), and δT is small compared to T_o for small $\kappa_\perp/\kappa_\parallel$. Such an expression may serve as the basis for simplified theoretical and numerical descriptions of heat transport in chaotic fields.