

Turbulent transport of heat and particles decoupled in a new operating regime observed on the Alcator-C tokamak

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Changes in edge turbulence result in increased heat confinement, advantageous for fusion, without unwanted confinement of particles.

A key challenge in fusion energy is to confine the input heat long enough for the hot ionized hydrogen, fuel, or plasma, to fuse and produce net energy. Over 25 years ago, the spontaneous formation of an edge transport barrier was discovered, which roughly doubles the energy confinement [1]. This “high confinement”, or H-mode, regime, is relied on in most ‘tokamaks’, a type of toroidal ‘magnetic bottle’, and foreseen for the international ITER project. However, these edge transport barriers also confine particles, including unwanted impurities and spent fuel which could contaminate and dilute the plasma, and prevent or extinguish the fusion reaction. Some means of expelling the particles is thus needed. This can be accomplished by naturally occurring bursts of plasma from the edge, but they are of concern since they may erode the material surfaces of a large tokamak.

A new regime is being studied on the compact, high field Alcator C-Mod tokamak at MIT which has an energy transport barrier similar to that in H-mode, without the unwanted increase in particle confinement [2]. This leads to steady, readily controllable densities and low radiated power, in most cases without any large-scale bursts. Edge and core temperatures increase dramatically, up to 5 keV (55million °C) (Figure 1), and energy confinement reaches or exceeds the H-mode scalings on which the ITER design is based. A general, gradual decrease in the broadband edge turbulence is seen as the barrier is formed. A weakly coherent mode appears at higher frequencies which may be responsible for regulating particle transport (Fig 2). The regime, named “I-Mode” has been obtained using RF heating and maintained in steady state for times greatly exceeding the confinement time scale. It has been studied over a wide range of plasma parameters, with toroidal magnetic field up to 6 T and plasma current up to 1.3 million amperes, and its access is favored by certain plasma shapes and magnetic topologies. Current experiments, to be reported at the APS-DPP meeting, seek to understand the physics underlying

this attractive regime, in particular the unusual decoupling of heat and particle transport, and an assessment of its prospects for burning plasma experiments in ITER.

[1] F. Wagner *et al*, Phys. Rev Letters **53** (1984) 1453-6

[2] D. G. Whyte, A. E. Hubbard, J. W. Hughes *et al*, Nuclear Fusion (2010) 105005.

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Invited Paper PI2.00006 [I-Mode regime with an edge energy transport barrier but no particle barrier in Alcator C-Mod](#), to be presented by Amanda Hubbard at 52nd Annual Meeting of the APS Division of Plasma Physics, November 8-12, 2010 Chicago, IL, 02:00 PM on Wednesday, 11/10/10

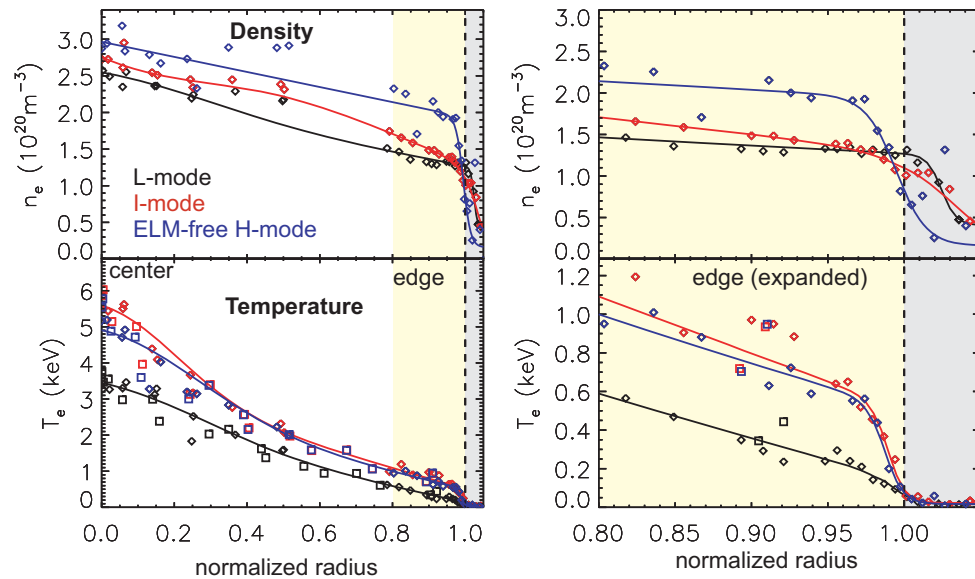


Figure 1: Temperature and density profiles, showing strong increase in core temperature (bottom left), and steep edge T gradients (bottom right) in I-mode (red curves) indicating reduced heat transport. In H-mode (blue) temperatures are similar but there is also a density barrier (top right), and increase in particle content.

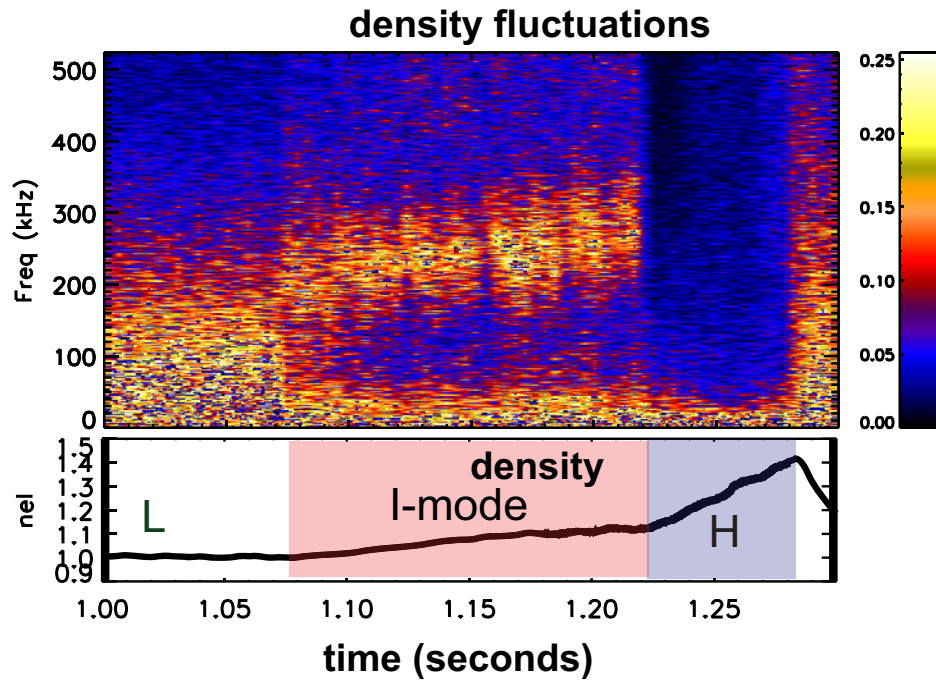


Figure 2: Density fluctuations in a discharge transitioning from “low confinement (L) mode” (left) with high, broadband turbulence, “I-mode” (red), with decreased turbulence and a weakly coherent mode at 250 kHz, and “high confinement (H) mode” (blue), with low turbulence but a strong increase in plasma density due to reduced particle transport.

Note: Improved versions of figures can be produced if this research highlight is selected.