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On the local nature of cold-pulse experiments in Alcator C-Mod, DIII-D and ASDEX Upgrade

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This work presents for the first time a self-consistent explanation for anomalous cold-pulse propagation – an enigmatic but universal transient transport phenomenon in fusion plasmas. For more than twenty years, edge-cooling experiments under certain conditions have shown evidence of the very fast increase of central electron temperature; a seemingly counter-intuitive response [1, 2]. Our capability to predict future fusion devices, as based on the paradigm of quasilinear local models of turbulent transport, has long been questioned for the claimed impossibility of local models to reproduce this cold-pulse behavior. Recent experiments in Alcator C-Mod [3, 4], DIII-D [5] and ASDEX Upgrade [6] have shed light on complementary aspects of this challenging phenomenology. Measured features of these experiments are remarkably well reproduced in theory-based integrated modeling simulations with the Trapped Gyro Landau Fluid (TGLF) turbulent transport model [7], including phenomenology in diverse conditions spanning a wide range of densities, currents and heating mixes, as shown in Fig. 1.

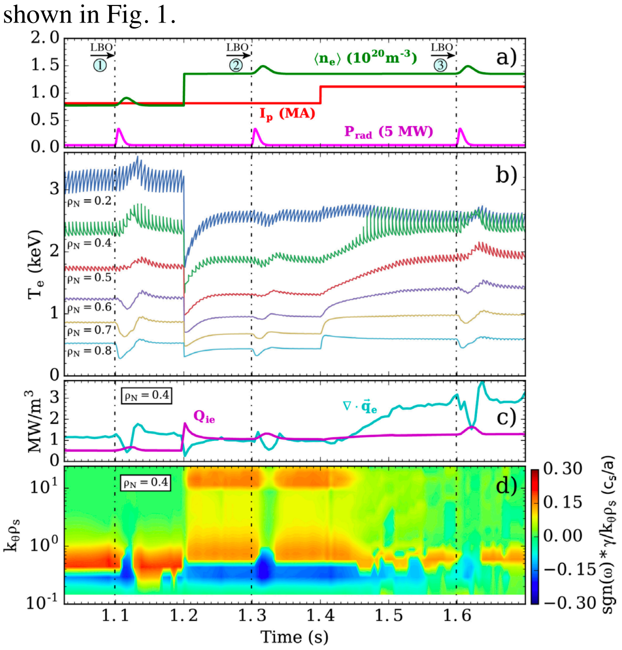

Fig. 1. Simulation results of density and current scan: (a) Plasma current, density and radiated power, (b) electron temperature, (c) collisional power and electron conducted power, and (d) linear growth rates. Reproduced from [4].

In the simulations, the apparent "non-local" effect is obtained through a multi-channel turbulent transport interaction in Trapped Electron Mode (TEM) turbulence. The close connection between particle and heat transport in TEM-dominated conditions produces a strong reduction of electron heat transport in response to the sudden flattening of the core density profile, caused by the peripheral laser ablation of impurities. The observed different electron temperature responses as a function of density, currents and heating mixes are consistently reproduced and explained by the transport properties of the different turbulence regimes that develop in the plasma.

These unprecedented results, which realistically simulate one of the most challenging dynamical responses of tokamak plasmas, provide an additional critical demonstration of the validity of local quasilinear models, currently used for transport predictions in ITER and SPARC [8] burning plasmas.

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