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A New Explanation of Sawtooth Phenomena in Tokamaks[1]

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The ubiquitous sawtooth phenomena in tokamaks are so-named because the central temperature rises slowly and falls rapidly, similar to the blades of a saw. First discovered in 1974, it has so far eluded a theoretical explanation that is widely accepted and consistent with experimental observations. We propose here a new explanation for sawtooth phenomena in auxiliary heated tokamaks that is motivated by our recent simulations and understanding of "flux pumping" in tokamaks[1]. In this theory, the role of the m=1 mode is primarily to generate a central dynamo voltage via a saturated interchange mode. This regulates the central safety factor, q_0, to be very near but slightly above unity with very low central magnetic shear. As the temperature and density profiles peak, they abruptly become unstable to centrally localized non-resonant pressure driven ideal MHD modes with poloidal and toroidal mode numbers (m,n) with m=n >1. It is these higher order modes interacting with each other that cause the sudden crash of the temperature profile, due to rapid E x B convection, not magnetic reconnection. Long time 3D MHD simulations of multiple cycles using M3D-C1 demonstrate this phenomenon, which appears to be consistent with many experimental observations: that q_0 changes very little during the crash and is near 1.0; that the crash can be very abrupt and fast, occurring on an ideal MHD time scale; and that rapid impurity penetration can occur during the crash, implying strong convection. This also possibly offers an explanation of how (1,1) impurity snakes can survive many sawtooth oscillations . Important elements of these simulations are that they use high toroidal mode number resolution and that they use inductive current drive, i.e. not purely RF. [1]Jardin, *et al*, Phys. Rev. Lett. **21** 215001 (2015), Krebs, *et al*, Phys. Plasmas **24** 102511 (2017)

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