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Collapse of core toroidal angular momentum due to the coupling of rotating magnetic islands in tokamaks[1]

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The dynamic, nonlinear evolution of tearing instabilities on DIII-D reveals a coupling of rational surfaces that can lead to phase-locking amongst multiple rotating magnetic island chains.[2] This loss of flow shear increases disruptivity, particularly at the low level of rotation expected in ITER. Bifurcation of differential mode frequency and fluid rotation in hybrid scenario discharges has been interpreted by comparison to a recently developed theory of nonlinear mode coupling.[3] Magnetic islands of different toroidal mode number couple to flatten the toroidal rotation profile, and the resulting phase-locked state is similar to the so-called "slinky" mode observed in reversed field pinch devices. Reduction of the edge safety factor increases the momentum transport, easily overwhelming the local torque density available from neutral beam injection. In discharges with $q_{95} \sim 4.5$, however, the participating modes do not remain phase-locked. In these cases, ECE-Imaging data have been used to show that the poloidal rotation of the composite, multi-helicity structure exceeds that of the measured carbon (and estimated deuterium) fluid flow. The present model of nonlinear 3-wave mode coupling does not generate the forces required to drive this rotation. Therefore, flow shear inversion represents a transition from phase-locking to a new regime of convective momentum transport in which additional mechanisms become important. These results highlight the importance of controlling multi-mode interactions in order to maintain stabilizing flow shear.

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[2]B. Tobias, et. al, Rev. Sci. Instrum. 85, 11D847 (2014).
[3]R. Fitzpatrick, Phys. Plasmas 22, 042514 (2015).