

Fishbone-like Instability at the Edge of ELM-free Quiescent H-modes in DIII-D*

M.F.F. Nave¹, K.H. Burrell², M.E. Austin³, J.S. deGrassie², W.W. Heidbrink⁴,
T.H. Osborne², E.J. Strait², P.B. Snyder², M.A. Van Zeeland²

¹*Associação EURATOM/IST, Instituto de Plasmas e Fusão Nuclear-Laboratório Associado, Instituto Superior Técnico, P1049-001, Lisbon, Portugal*

²*General Atomics, PO Box 85608 San Diego, California 92186-5608, USA*

³*University of Texas, Austin, Texas, USA*

⁴*Center for Energy Research, University of California-Irvine, Irvine, California 92697, USA*

Quiescent H-modes (QH-mode) are high confinement plasmas with an edge transport barrier free of Edge Localized Modes (ELMs) [1]. The ELM-free phases are characterized by edge MHD activity, known as the Edge Harmonic Oscillations (EHO), usually reported as continuous, saturated, coherent modes with low toroidal mode numbers, most dominantly $n=1-3$ [2]. The term EHO has however been applied loosely to a variety of edge MHD activities that appear to delay ELMs by clamping the pressure at the top of the pedestal. In some QH DIII-D pulses the continuous coherent modes are substituted by broadband activity [3], while in others reported here, the EHO appears in the form of repetitive bursts resembling fishbone activity. Like the continuous EHO, electron cyclotron emission data indicates that the short bursts, with mode numbers $n=3$ and $n=4$, are localized close to the separatrix. In one example shown here, $n=3$ bursts decreasing in frequency are seen in anti-phase with $n=4$ bursts that increase in frequency, suggesting that each mode is localized on each side of the radial electric field well observed in QH discharges just inside of the separatrix [3]. The bursts correlate with fast ion losses measured with the beam ion loss detector. For the $n=3$ the observed mode frequency is close to the average precession frequency of the injected beam ions, suggesting that they might be driven by fast ions. The EHO has been previously interpreted as a low- n external kink (peeling) mode destabilized by a combination of edge pressure, current and rotational shear [4]. This interpretation is applicable to both bursts and continuous EHOs, as both lie in the same region of the edge stability diagram close to the external kink boundary. However the bursts draw attention to the importance of fast ions in the edge stability of these plasmas, where the external kink (similarly to the internal kink) might have become more unstable due to the resonant interaction of the MHD mode with a fast ion population [5].

[1] K.H. Burrell *et al.*, Phys. Plasmas **8**, 2153 (2001)

[2] W.P. West *et al.*, J. Nucl. Mater. **337-339**, 420 (2005)

[3] K.H. Burrell *et al.*, Plasma Phys. Control. Fusion **46**, A165 (2004)

[4] P.B. Snyder *et al.*, Nucl. Fusion **47**, 961 (2007)

[5] G.Z. Hao *et al.*, Phys. Rev. Lett. **107**, 015001 (2011)

*This work was supported in part by the US Department of Energy under DE-FC02-04ER54698, DE-FG03-97ER54415, and SC-G903402.