Abstract Submitted
for the APR06 Meeting of
The American Physical Society

Nonlinear Growth of a Line-tied g-Mode Near Marginal Stability[1]

P. ZHU, C. C. HEGNA, C. R. SOVINEC, University of Wisconsin-Madison — A theoretical framework has been developed for the study of the nonlinear gravitational (g-) mode of a line-tied flux tube near marginal stability. The theory is based on an expansion using two small parameters, $\epsilon \sim |\boldsymbol{\xi}|/L_{\rm eq} \ll 1$, and $n^{-1} \sim k_{\|}/k_{\perp} \ll 1$, with $\boldsymbol{\xi}$ denoting the plasma displacement, $L_{\rm eq}$ the characteristic equilibrium scale, $k_{\|}$ and $k_{\perp}$ the dominant wavenumber of perturbation parallel and perpendicular to equilibrium magnetic field lines respectively. When $\epsilon \sim n^{-1}$, the Cowley-Artun regime is recovered where plasma is to the lowest order incompressible [S. C. Cowley and M. Artun, Phys. Rep., **283**, 185-211 (1997)]. The detonation regime where the nonlinear growth of the mode is finite-time singular is a narrower subset of the Cowley-Artun regime. However, the validity of this regime breaks down when $\epsilon \gg n^{-1}$. In the intermediate nonlinear phase when $\epsilon \sim n^{-1/2}$, the lowest order plasma compression [$\sim \nabla\cdot\boldsymbol{\xi} \sim \mathcal{O}(1)$] is nonzero. Direct MHD simulations with both a finite difference code and NIMROD indicate that the mode remains bounded in magnitude with a slightly reduced nonlinear growth [P. Zhu, A. Bhattacharjee, and K. Germaschewski, to appear in PRL (2006); P. Zhu, C. C. Hegna, and C. R. Sovinec, DPP2005]. During this phase, the coupled growth of the mode amplitude $\boldsymbol{\xi}$ and plasma compression may contribute to a nonlinear stabilization. The corresponding governing model equations for this intermediate nonlinear phase are derived.

[1]Supported by U.S. DOE Grant No. DE-FG02-86ER53218.

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Date submitted: 11 Jan 2006 Electronic form version 1.4