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Energetic particle driven mode activity: advances in understanding from linear through hard nonlinear regime.

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We report on developments in understanding the physics of energetic particle driven modes in toroidal confinement. These span the range of linear, through weak nonlinear and finally the hard nonlinear regime.

Ion cyclotron heating upgrades in the H-1 heliac have enabled a study of the change in linear stability and mode excitation with increasing power. [1] A heating power scan in mixed hydrogen/helium plasmas reveals a change in frequency-stationary mode activity with increasing heating power. At low power (<50 kW) modes with beta-induced Alfvén eigenmode (BAE) frequency scaling are observed. At higher power modes consistent with an analysis of nonconventional global Alfvén Eigenmodes (GAEs) are observed. Calculations of linear growth rate using a local flux surface stability code agree with global stability calculations, and suggest the future potential of MHD spectroscopy to infer the temperature of the energetic species. The calculation of kinetic and continuum damping in 3D is new.

Bursty mode activity is observed during early neutral beam heating in KSTAR plasmas, before current flat top while the q profile is still evolving. The magnitude of the activity increases with early beam heating, and reduces with the addition of resonant magnetic perturbation magnetic field coils. HAGIS simulations with plausible distribution functions are utilised, which demonstrate that the lowest frequency mode satisfies the condition for wave drive. The mode is downward chirping, demonstrating that either the plasma is drag-dominated, or anisotropy in pitch angle is present.

Finally, we extend a study of long-range frequency chirping of collisionless nonlinear waves carrying a population of phase-mixed trapped particles, whose existence is determined by the fast passing particles, to cases where these particles do not move freely and their motion is bounded to restricted orbits. [2] This extended model captures the range of particles motion (trapped/passing) with energy and thus represents a more realistic 1D picture of the long range sweeping events observed for weakly damped modes.

[1] M. J. Hole *et al*. Plasma Phys. Control. Fusion 59 (2017) 125007

[2] H. Hezaveh , Z.S. Qu, B. Layden and M.J. Hole, Nucl. Fusion 57 (2017) 126010