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Large Gyroradius Effects on Gradient-Driven Plasma Instabilities[1]

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Instabilities in collisionless low-beta plasmas dictate cross-field transport properties. While cross-field instabilities are presently understood through the lens of reduced models like fluid and gyrokinetic descriptions, implicit assumptions of thermodynamic equilibrium or low frequency are often not applicable. Finite Larmor radius (FLR) effects, in particular, can significantly alter plasma behavior on scales that are not captured by reduced models. Kinetic simulations offer a generalized means to study plasmas far from the fluid limit; however, characterizing linear and nonlinear dynamics requires an ability to initialize and capture equilibria that satisfy the steady-state governing equations. To that end, a versatile method is developed to construct self-consistent two-species kinetic equilibria in which ion gyroradii are comparable to gradient scale lengths. By admitting customizable spatial profiles, the exact equilibria enable the targeted study of isolated physics. The method and a noise-free fourth-order Vlasov-Poisson solver are leveraged to study the linear and nonlinear dynamics of Kelvin-Helmholtz and lower-hybrid drift instabilities in nonuniform plasmas. The approach advances the state of the art by enabling comprehensive investigation of FLR-modulated instabilities in experimentally-relevant configurations. The simulations shed light on transport properties and demonstrate how FLR effects modify instability behavior. Rigorous cross-comparisons with theory and two-fluid simulations help parse the role of kinetic physics. The study has important implications for cross-field transport in pulsed power systems, the magnetosphere, Hall thrusters, and magnetically confined plasmas. These techniques expand the scope of plasma dynamics that can be captured using kinetic simulations.

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