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Toward a nonlinear Schroedinger equation for the description of geodesic-acoustic-modes in tokamaks: Analytic gyrokinetic studies of the nonlinear self-interaction

The geodesic-acoustic-mode (GAM) is a plasma oscillation observed in fusion reactors with toroidal geometry and is recognized to be the nonstationary branch of the zonal flows. Prior studies have established that as a direct consequence of nonlinear gyrokinetic theory, the GAM dynamics is well described by an equation of Schroedinger type - i. e. an equation whose linear contribution is exactly of the same form as the linear Schroedinger equation, while the nonlinear dynamics necessitates an integro-differential expression.

The presented work takes a closer look into the nonlinear contributions by deriving approximate, but well-defined analytic expressions from the (exact) integro-differential operators. At the lowest order of accuracy, prior numerical studies anticipate the retrieval of a cubic nonlinear Schroedinger equation. This may come unexpected since nonlinear interactions usually have a quadratic structure, such as e. g. the $\vec{E}\times\vec{B}$-nonlinearity. The third power is found to stem from an interaction of quadratic structures generated by the GAMs (with oscillation frequencies that are either zero or twice the GAM frequency) with the GAM itself. Analytic results are compared to gyrokinetic simulations.

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