Gyrokinetic theory with polynomial transforms: a model for ions and electrons in maximal ordering

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Abstract

We propose a novel derivation of the gyrokinetic field-particle Lagrangian for non-collisional ion-electron plasmas in a magnetic background with strong variations (maximal ordering). Our approach follows the two-step reduction process, where the guiding-center coordinate transformation is followed by the gyrocenter coordinate transformation in the single-particle phase space. For the first time both steps are addressed within a unique methodology, based on near-identity coordinate transformations constructed as polynomial transforms. These are well-defined transformations composed of a finite number of terms that are linear and algebraic with respect to the generating functions. The derivation is carried out in a fully non-dimensional framework, based on parameters governing the magnetic fusion experiments ASDEX Upgrade and ITER. Our method leads to a gyrokinetic Vlasov-Maxwell model for ions and electrons, derived without the use of Lie perturbation methods. It is found that, based on the employed ordering, curvature terms such as the gyro-gauge term and the Baños drift appear at first order in the ion Hamiltonian, whereas ion polarization terms appear only at second order. By contrast, curvature terms are absent from the first-order electron Hamiltonian, where instead magnetic flutter plays a role.