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Action-Angle Formulation of Charged Particle Dynamics in Toroidally Confined Plasmas

YANNIS KOMINIS

School of Applied Mathematical and Physical Sciences
National Technical University of Athens, Athens 15780, Greece
gkomin@central.ntua.gr

Charged particle dynamics under the presence of electromagnetic fields is one of the main paradigms where the modern theory of nonlinear Hamiltonian dynamics and chaos has been applied [1]. Such complex dynamics crucially determines particle energy and momentum transport in toroidally confined fusion plasmas. Particle dynamics are studied in terms of the *Guiding Center* (GC) approximation, and are integrable under magnetic field symmetry conditions, such as axisymmetry or helical symmetry. However, the presence of spontaneously or intentionally introduced symmetry-breaking, multi-scale electromagnetic perturbations results in non-integrable dynamics and chaos [2].
In this work, we introduce a novel integrable system for the unperturbed GC motion and we analytically calculate the *Action-Angle variables* of the system as well as the *Orbital Spectrum* consisting of the frequencies in all degrees of freedom [3]. The system serves as a starting point for the application of canonical perturbation theories and numerical studies under the presence of symmetry-breaking perturbations. The unique advantages of the Action-Angle formulation are discussed, in terms of time-scale separation, derivation of reduced kinetic models, a priori knowledge of the exact locations of the phase space where resonances take place, and their implications for charged particle transport [4].

References

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