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## Nonlinear covariant kinetic theory of magnetoplasmas

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Recently, an increasing interest in astrophysical as well as laboratory plasmas has been manifested in reference to the existence of relativistic flows, related in turn to the production of intense electric fields in magnetized systems [1]. Such phenomena require their description in the framework of a consistent relativistic kinetic theory, rather than on relativistic MHD equations, subject to specific closure conditions. Single-particle relativistic gyrokinetic theory appears therefore a basic prerequisite for a consistent formulation of relativistic theories. The purpose of this work is to extend the relativistic single-particle guiding-center theory developed by Boghosian [2], Pozzo *et al.* [3] and Beklemishev *et al.* [4] to include both effects due to strong quasi-stationary EM fields as well as the nonlinear treatment of possible EM perturbations characterized by small wavelengths which may naturally arise in such systems. For this purpose, a closed set of relativistic gyrokinetic equations, consisting of the collisionless relativistic kinetic equation, expressed in hybrid gyrokinetic variables (*here denoted as hybrid relativistic gyrokinetic Vlasov equation*) and the averaged Maxwell's equations, is derived for an arbitrary four-dimensional coordinate system. The guiding-center dynamics of charged particles and the gyrokinetic transformation are obtained accurate through second order of the ratio of the Larmor radius to the equilibrium scale length. The wave-terms with arbitrary wavelength ($k\rho \sim 1$) are described in the second order (nonlinear) approximation with respect to the amplitude of the wave. The same approximations are used in the derivation of the gyrophase-averaged Maxwell's equations. The derivation is based on the perturbative Lagrangian approach with a fully relativistic, four-dimensional covariant formulation expressed in terms of arbitrary *hybrid* (i.e., generally non-canonical) variables, which allows relativistic drift velocities as well as consistent description of gravitation. Our results improve on existing limitations of the relativistic gyrokinetic theory [2] and extend the earlier formulation of Beklemishev *et al.* [4] in three aspects: the parallel electric field is not necessarily small; there is no limitation on the parallel wavelength of perturbations; second order (nonlinear) contributions are explicitly calculated.

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