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Geometric Gyrokinetic Theory for Edge Plasmas[1]

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A set of generalized gyrokinetic equations valid for the edge plasmas has been derived using a geometric method. This formalism allows large-amplitude, time-dependent background electromagnetic fields to be developed fully nonlinearly in addition to small-amplitude, short-wavelength electromagnetic perturbations. In its most general form, gyrokinetic theory is about a symmetry called gyro-symmetry. The objective of geometric gyrokinetic theory is to decouple the gyro-phase dynamics by finding the gyro-symmetry. This is fundamentally different from the conventional gyrokinetic concept of "averaging out" the "fast gyro-motion." The starting point is the Poincaré-Cartan-Einstein 1-form on the 7D phase space which determines particles' dynamics and realizes the velocity integrals in kinetic theory as fiber integrals. The infinitesimal generator of the gyro-symmetry is then constructed by applying the Lie coordinate perturbation method. General gyrokinetic equations are then developed as the Vlasov- Maxwell equations in the gyrocenter coordinate system, rather than a set of new equations. Because the general gyrokinetic system is geometrically the same as the Vlasov-Maxwell equations, all the coordinate-independent properties of the Vlasov-Maxwell equations, such as energy conservation, momentum conservation, and phase space volume conservation, are automatically carried over to the general gyrokinetic system by the pullback transformation. With subsidiary orderings, explicit and practical results can be obtained from the new formalism. For example, the pullback transformation in the gyrokinetic Poisson equation can be explicitly expressed in terms of moments of the gyrocenter distribution function, with the important gyro-orbit squeezing effect due to the large electric field shearing in the edge and the full finite Larmour radius effect for short wavelength fluctuations.

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